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Pollutant Loading Reductions for the Revised Effluent Limitations Guidelines for Concentrated Animal Feeding Operations

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Engineering and Analysis Division
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Pollutant Loading Reductions for the Revised Effluent Limitations Guidelines for Concentrated Animal Feeding Operations

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I. Introduction

Section 301(d) of the Clean Water Act (CWA) directs the Environmental Protection Agency (EPA) to periodically review and revise, if necessary, effluent limitations guidelines and standards promulgated under CWA Sections 301, 304, and 306. Animal feeding operations (AFOs) have been identified as a major source of pollutants impairing surface water and ground water in the United States; therefore, EPA is revising the existing effluent guidelines for AFOs. The final regulation requires beef, dairy, veal, heifer, poultry, and swine AFOs to handle their manure in a more environmentally sound manner, including upgrading facilities to decrease the runoff potential from feedlots, limiting land application of manure based on nitrogen (N) and phosphorus (P) agronomic rates, and encouraging other technologies (e.g., treatments that lower the environmental impact or reduce the manure water content).

To support its rule revision, EPA performed computer model simulations of 13,500 different Sample Farms or AFO facilities (i.e., various combinations of AFO type, size, location, and pollutant management). For each Sample Farm, EPA estimated edge-of-field pollutant loadings (in pounds per year per acre of cropland) to serve as a basis for scaling up to a total national estimate of the 25-year average annual pollutant discharge. In sum, the interaction of AFO facilities with the environment was gauged based on approximately *228 million simulated days* of Sample Farm performance. In addition, EPA's assessment incorporated pollutant loadings from feedlots and common manure storage structures, representing industry preferences and management tendencies.

This document describes the methods used by EPA to analyze AFO/environment interaction and then estimate pollutant loads and potential pollutant load reductions associated with revising existing AFO guidelines. Note that the potential benefits associated with estimated national pollutant loads reductions are detailed in *Environmental and Economic Benefit Analysis of Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for Concentrated Animal Feeding Operations* and the assessment of rule revision costs is documented in *Economic Analysis of the Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for Concentrated Animal Feeding Operations*.

A. Delineation of Potentially Affected Farm Cropland

EPA's effluent assessment estimates the national sediment, nutrient, pathogen, and metals loadings to surface waters and groundwater under the current effluent limitations guidelines (prerevised regulation or baseline) and after the implementation of various effluent limitations guidelines technology options (postregulation modeling scenarios). EPA's national assessment started with an estimation of manure generation and then progressed to an estimation of fertilizer-based (manure and synthetic) pollutant loads. Key to assessing pollutant loads is an understanding of the land application of manure to croplands; croplands are the predominant destination for AFO manure.

To provide a consistent basis for comparison, EPA evaluated pollutant loads at both animal feedlot operation (AFO) and non-AFO facilities for a cropland area totaling 21 million acres nationally. As detailed below, within the 21 million acres are multiple categories of AFO farms, and non-AFO farms that acknowledge differences in fertilizer requirements and application rates. Note that EPA's postrevision options do not affect the generation of manure and manure-related pollutants (i.e., production rates are constant), but only the management of AFO manure generated. Figure 1 indicates how, for baseline and three groupings of options (potential revised effluent guidelines defined below), EPA maintained a constant total of 21 million acres in its assessment, to enable evaluation of AFO and non-AFO acres. In EPA's assessment the total acreage remains constant at all levels: farm, farm type (sector), and regional and national levels for prerevision and postrevision conditions.

Additional information on the characterization of cropland acres potentially affected by EPA's rule revision is provided in Table 1. Table 1 associates AFO manure generation with the cropland disposal for three categories of AFO facilities. Category I AFOs are relatively self contained and generally less affected by proposed rule revisions, because their manure generation does not exceed the agronomic fertilizer requirements of their cropland acreage. Category II AFOs have insuffiicent cropland to make full use of the manure they generate, so they either overfertilize their croplands (a common condition under current guidelines) or

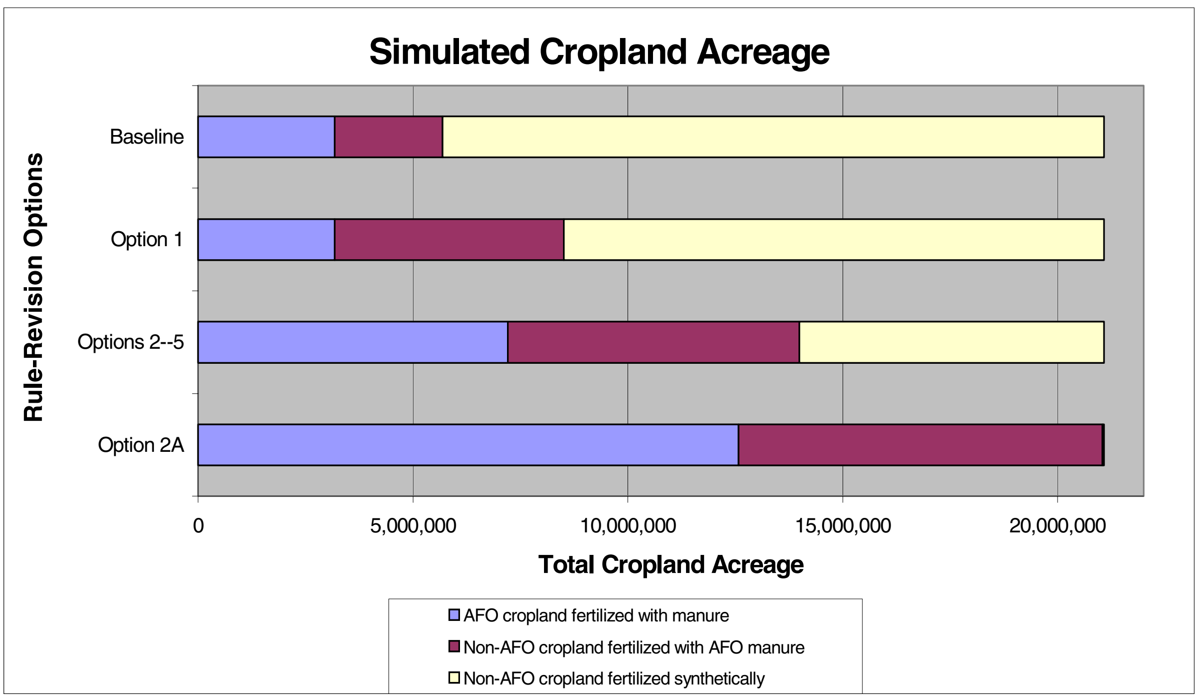


Figure 1. Delineation of cropland potentially affected by rule revisions

Table 1. Characterization of Farm Cropland Potentially Affected by Rule Revisions, Based on Farm Conditions

Farm Condition	Agronomic Limit Based on Crop Selection	Baseline Acres (Prerevision)	Option 1 Acres	Option 2--5 Acres	Option 2A Acres
Category I - AFO cropland where manure is applied at agronomic rates.					
	N-based	1,415,812	1,415,812	784,137	0
	P-based	0	0	1,976,708	4,893,744
Category II - AFO cropland for facilities where manure application exceeds agronomic rates					
	N-based within AFO facilities	1,755,734	1,755,734	910,503	0
	P-based within AFO facilities	0	0	3,571,789	7,840,241
	N-based for off-site non-AFO facilities	350,284	3,171,869	4,543,510	6,137,784
Category III - AFO farms with no land for manure application (Values are for non-AFO acreage receiving manure from AFOs).*					
	N-based	2,165,781	2,165,781	2,165,781	2,165,781
Total national acres in N-based condition (AFO manure fertilized)		5,687,611	8,509,196	8,403,931	8,303,565
Total national acres in P-based condition (AFO manure fertilized)		0	0	5,548,497	12,733,985
Non-AFO farms using commercial fertilizer (used to ensure a consistent total acreage for cropland when comparing rule-revision options).					
	N-based and P-based	15,387,767	12,566,182	7,122,950	37,837
Total National Acreage Simulated		21,075,378	21,075,378	21,075,378	21,075,387

* Farms without available acreage to dispose of manure are assumed to disperse their manure to croplands of non-AFO farms at a rate less than five times N-based agronomic levels.

distribute their manure off-site to non-AFO cropland. Finally, Category III AFO facilities actually do not have cropland, so they have to disperse all their manure to non-AFO croplands.

For most rule-revision options (described below), departure from baseline conditions entails decreasing the overapplication of manure by linking application rates to crop requirements. As shown in Table 1, EPA's assessment delineated between N-based and P-based fertilized cropland. Under the options considered, better use of AFO manure also results in a *decrease* in synthetic (commercial) fertilizer application for non-AFO cropland acres. This reduction in synthetic fertilizer reduces the total estimated national pollutant loads, as detailed below. Readers should be aware that application of manure on an agronomic N basis generally results in an overapplication of P, a practice known to cause deleterious effects on surface waters. In addition, application of manure at an agronomic P basis results in a deficit of N. When assessing rule revisions, EPA assumed crops would receive the necessary commercial fertilizer to fulfill the crop nitrogen requirements, regardless of whether it is N or P based. In its assessment, EPA considered two possible (and relatively common) manure application technologies: direct application to field surfaces and incorporation of manure.

Based on the farm categories defined in Table 1, Table 2 outlines what the rule-revision options entail in terms of nutrient application for AFO and non-AFO acres. Table 2 indicates how potential options establish requirements for agronomic fertilizing that is either N based or P based, and changes the categorization of cropland acres under management. It should be noted that EPA used P-based fertilization or fertilization at a phosphorus rate to select 21 million acres as the total farm area to evaluate. In general, P-based fertilization at agronomic levels using manure requires about seven times the acreage as N-based fertilization to avoid overapplication.

Option 1 differs from baseline conditions in the large decrease (about 3 million acres) in cropland receiving excessive fertilization (currently up to five times the N-based agronomic rate), and the use of manure instead of synthetic fertilizer. Options 2 through 5 produce the same shifts. However, because P is used as the basis, approximately 8 million acres of cropland are expected to be affected. Under Option 2A all farms are assumed to apply manure to onsite cropland at the P-based rate, with supplemental nitrogen added to bring the N applied to the crop removal rate. Option 2A was done as a sensitivity analysis to determine impacts if all onsite manure was applied on a P basis.

As depicted in Figure 1 and Table 1, commercial fertilizer was extensively used, especially under baseline conditions, for option 1 and option 2. Commercial fertilizer was needed to compare the various options. For example, sediment yields on a per acre basis were relatively uniform despite the application rate of manure or commercial fertilizer. If land with commercial fertilizer applied was not used, sediment from baseline conditions would appear much smaller than the other options. By including commercial fertilizer, an equal land base was created to compare, evaluate, and process the results for the various scenarios under analysis.

Table 2. Overview of Regulatory Options

Description of Assessed Regulatory Condition	Description of Major Features	
	AFO Acreage (onsite)	Non-AFO Acreage
Baseline (prerevised regulatory baseline)	Category I, II, and III land receives manure at N- to 5N-based rates or commercial fertilizer	Manure applied at agronomic N-based rate. Cropland not receiving manure has commercial fertilizer applied as needed to track a fixed total acreage.
Option 1	Category I, II, and III land receives manure at N-based rates or commercial fertilizer	
Options 2 – 5	Category I, II, and III land receives manure at N- or P-based rates depending on current soil P levels or commercial fertilizer	
Option 2a	Category I, II, and III land receives manure at P-based rates or commercial fertilizer	

B. Methodologic Overview

To estimate per farm nutrient, sediment, pathogen, and metals loadings (and potential loadings reductions resulting from options in Table 2), EPA developed 13,500 individual Sample Farm models. These individual models estimate manure generation and pollutant discharge (after management) for a wide range of conditions. Each Sample Farm model represented a single combination of animal type, farm size class, manure application technique, manure application rate, and farm location. EPA's estimate of the annual national total pollutant load was calculated using per farm pollutant loads from the suite of Sample Farm models and a detailed population breakdown of AFO facilities nationwide. As detailed below, each Sample Farm model is customized to represent the behavior of a fraction of the total AFO facility population. This document describes how the suite of models was customized to reflect management practices and animal waste management systems, as well as regional physiographic information regarding the soil, rainfall, hydrology, and crop rotation.

Figure 2 uses an example sector (beef/cattle) to show how modeled *per farm* pollutant manure generation is estimated for individual farm sizes in a representative number of locations (physiographic conditions). Additionally, per farm pollutant generation is adjusted to reflect the efficacy of various management techniques for each of five farm size classes analyzed in each

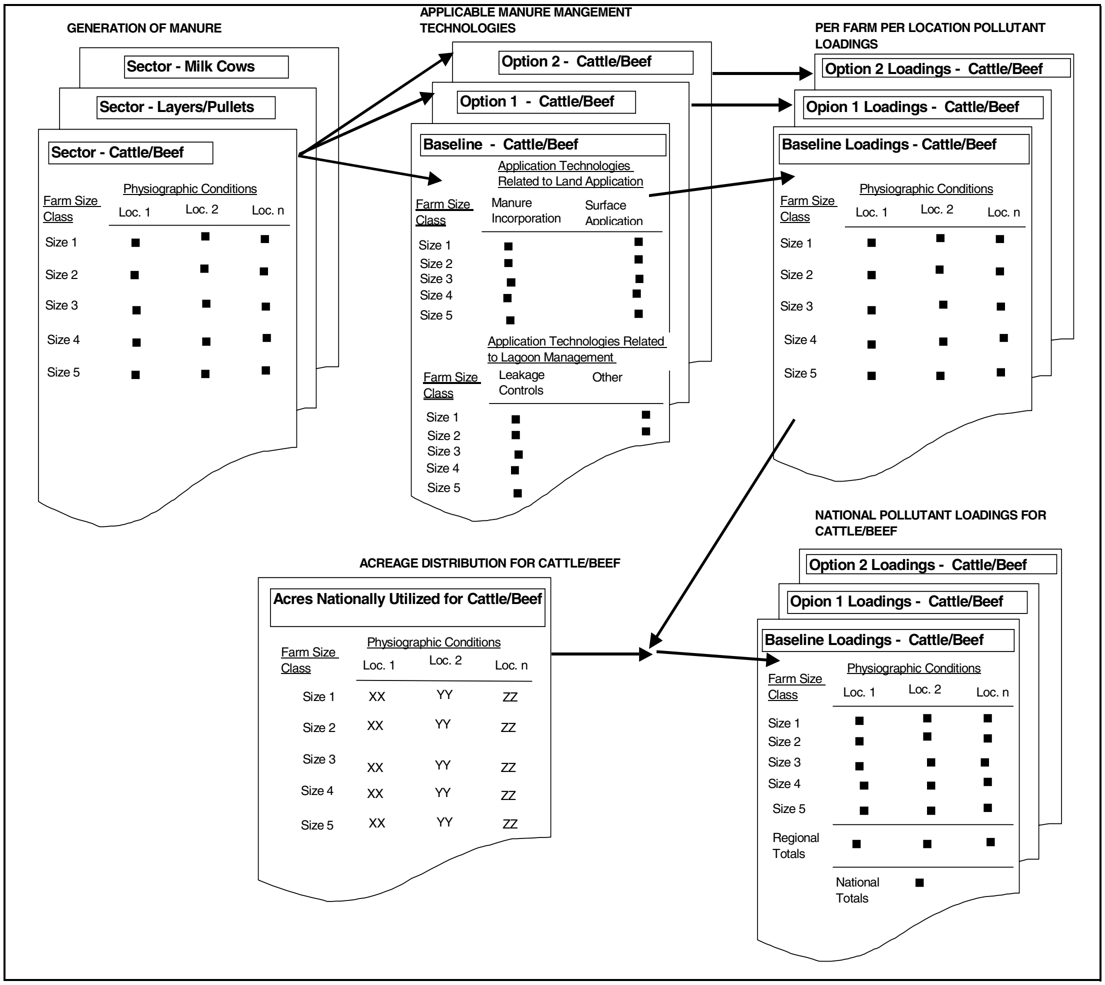


Figure 2. Conceptual view of CAFO pollutant loadings assessment methodology.

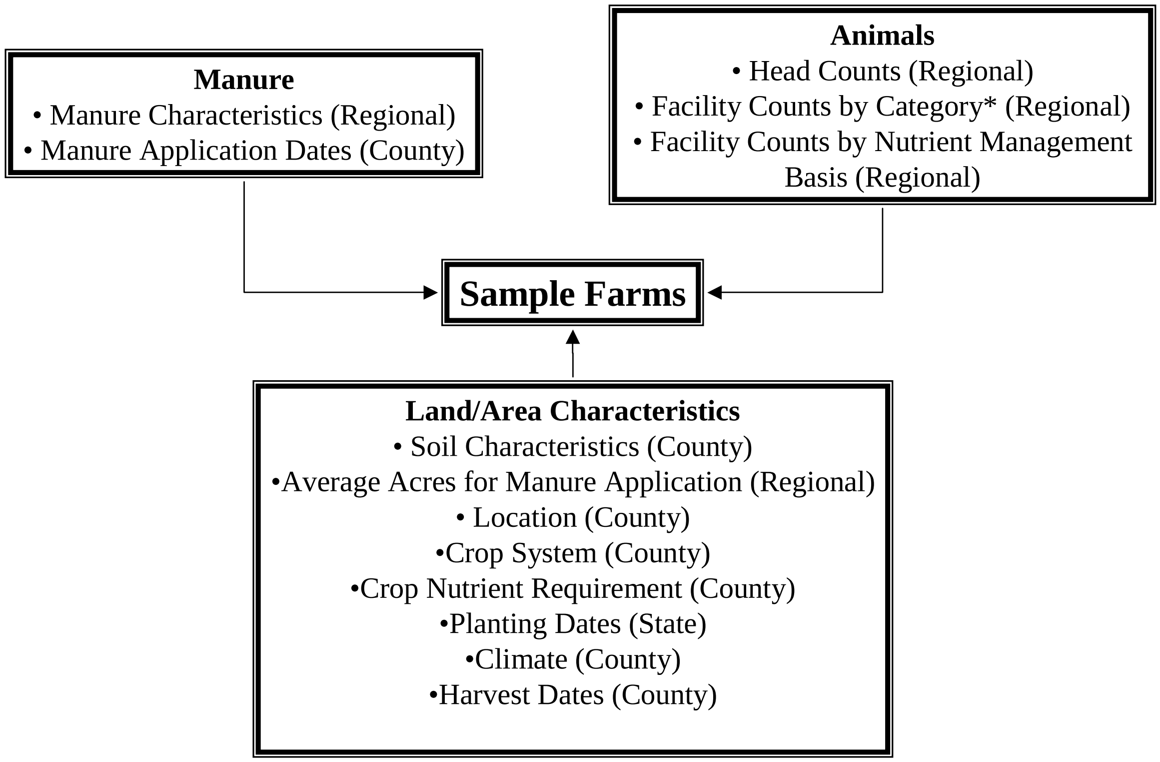
location and incorporation of pollutants generated from the production area. For example, because manure generated at CAFOs is stored in ponds or piles (for some sectors), EPA's assessment acknowledges the efficacy management of these storage systems and the potential storage system improvements that reduce pollutant discharges from the animal production area. In addition, EPA also evaluated the influence of manure application (surface and incorporation) to gauge potential reductions in pollutant discharge on a per farm basis. In summary, per farm pollutant loads were calculated based on manure generation, less plant uptake but adding loads because of storage system leakage and other runoff pollutants from the production area. Figure 2 illustrates how per farm pollutant loads (postmanagement discharge) are scaled up to produce regional load totals using the population of farms. Regional totals are then further aggregated into a single national loading. Repeating this process for all AFO sectors (farm types) for baseline and all regulatory options (options that revise current AFO management practices) provides the basis for assessing potential national environmental benefits.

The conceptual presentation in Figure 2 is expanded greatly within this document, including an extensive discussion of data sources, modeling assumptions, and model sensitivity. However, by using 13,500 different Sample Farm models, EPA has sought to produce estimates of potential national pollutant reductions through a process that acknowledges the diversity of farm conditions. To account for a wide range of natural conditions, EPA based its assessment on 25 years of simulated farm performance (a total simulation time of 33 million days of farm behavior for each option evaluated). EPA calculated the average annual pollutant loads based on the 25 years of performance and used them to compare rule-revision and baseline conditions. To the maximum extent possible, the modeling assumptions made by EPA do not inherently favor or disfavor the revision of existing effluent guidelines for stricter regulation of the AFO industry.

Simulations were conducted using these representative Sample Farms, along with additional information on manure pollutant generation and the cropping system specific to AFOs under baseline and postregulation model simulation conditions. Baseline Sample Farm conditions represent the current management practices in use across the nation (see the Cost Report for the complete descriptions and data sources). Baseline Sample Farm model simulations assume that all AFO-generated manure was applied to cropland and pasture acreage (which includes all AFO owned and rented acres as obtained from the 1997 Census of Agriculture, USDA, 2000a).

The Sample Farms were developed from many data sources that provide information on different geographic scales. Figure 3 illustrates the geographic scale for data used to develop the Sample Farm models. In summary, the data scale used by EPA to characterize performance is on a county, state or regional basis. As extensively detailed later, EPA parameterized some farm (model) characteristics on a regional basis (a single region contains between 4 and 14 states). For example, monthly evaporation rates were set regionally. In addition, important regional information on farm activities was obtained from queries using the 1997 Census of Agriculture data (USDA, 2000a). Cropping preferences and corp rotational patterns were also set regionally.

As noted in Figure 3, other inputs into Sample Farm models are on a state or county geographic scale to provide greater representation of local conditions. Soil parameters and daily precipitation records are examples of county-level parameters. As discussed below, EPA assessed soil data in USDA, NRCS's State Soil Geographic Database (STATSGO, USDA, 1995) for top-producing counties (locations currently preferred by AFO facilities) to identify common soil characteristics. Soil data were then used to estimate probable countywide and statewide soil characteristics and behavior. In addition, EPA assessed precipitation based on synthetic rainfall amounts provided by CLIGEN (the synthetic climate generator used in the Water Erosion Prediction Project) to find the closest gauge to the center of top-producing counties to characterize the climatic conditions in the county.



* Category refers to facilities that (1) have enough land to apply manure, (2) have insufficient land to apply manure, or (3) have no land for manure application

Figure 3. Data and spatial scale used to develop Sample Farms.

II. Model Selection and Characteristics

A. Potential Pollutant Loading Estimate Models

Analytical and mathematical models can be used to estimate pollutant loading from agricultural areas by simulating the physical, chemical, and biochemical processes that govern the transport of water and sediment. For example, field-scale models such as Groundwater Loading Effects of Agricultural Management Systems (GLEAMS) (Knisel et al., 1993) and Erosion-Productivity Impact Calculator (EPIC) (Sharpley and Williams, 1990) provide estimates of pollutants in runoff and sediments that are leaving the field boundaries. Field-scale models permit a detailed assessment of pollutant load generation and the influence of various management technologies, but generally require the detailing of variation in soil and crop type.

On the other hand, watershed-scale models such as the Soil Water Assessment Tool (SWAT) (Arnold et al., 1990) and Agricultural Nonpoint Source (AGNPS) (Young et al., 1989) are models that simulate pollutant loading at the watershed outlet. Watershed models are generally less data intensive than field boundary models because they use spatially averaged data, or they simplify the characterization of the watershed land area. For example, watershed models require lumping or averaging of soil and crop parameters to account for the 10 to 100 individual farm fields that constitute the land area within the typical small rural watershed. However, watershed-level modeling can become more complex than field-scale models because nonagricultural pollutant sources (e.g., industrial and urban land use areas) also contribute to the watershed total pollutant load.

Because EPA's existing and proposed effluent limitations guidelines will apply at the facility or farm level, EPA identified the benefits of using a field-scale model to evaluate the effect of the proposed regulation. EPA chose to use the GLEAMS model to estimate pollutant loads in surface runoff, sediment, and groundwater leaching from AFO facilities. The GLEAMS model is a field-scale, physically based continuous model that can be used to evaluate the effects of various agricultural management systems on the movement of water, soil, and agricultural pollutants to water sources. The GLEAMS model (Knisel et al., 1993) simulates both hydrology and erosion processes in the field, as well as biochemical processes related to pollutant transport such as chemical transformation and plant uptake.

In addition, EPA also performed limited watershed-wide modeling using the BASINS/SWAT model model. Case studies conducted at the watershed scale using BASINS/SWAT can be found in the CAFO Water Docket (Document Control Numbers 321327 and 321328).

B. Overview of GLEAMS

The GLEAMS model requires the specification of input parameters that best represent the soil, crop, climate, and management characteristics of the agricultural area to be simulated. The hydrology component of the GLEAMS model uses daily climatic data to calculate the water balance in the root zone. Precipitation is partitioned between surface runoff and groundwater leaching through the use of the U.S. Department of Agriculture (USDA) Soil Conservation Service curve number method (USDA-SCS, 1972). A storage-routing technique is used to simulate the redistribution of infiltrated water within the root zone and percolation beyond the root zone to groundwater sources. Evapotranspiration is estimated using the Penman-Monteith method (Monteith, 1965).

The application of GLEAMS within EPA's assessment is demonstrated in Figure 4. EPA's basic approach was to characterize pollutant inputs from manure and synthetic fertilizers and then perform a field-level assessment of the pollutant fate and transport.

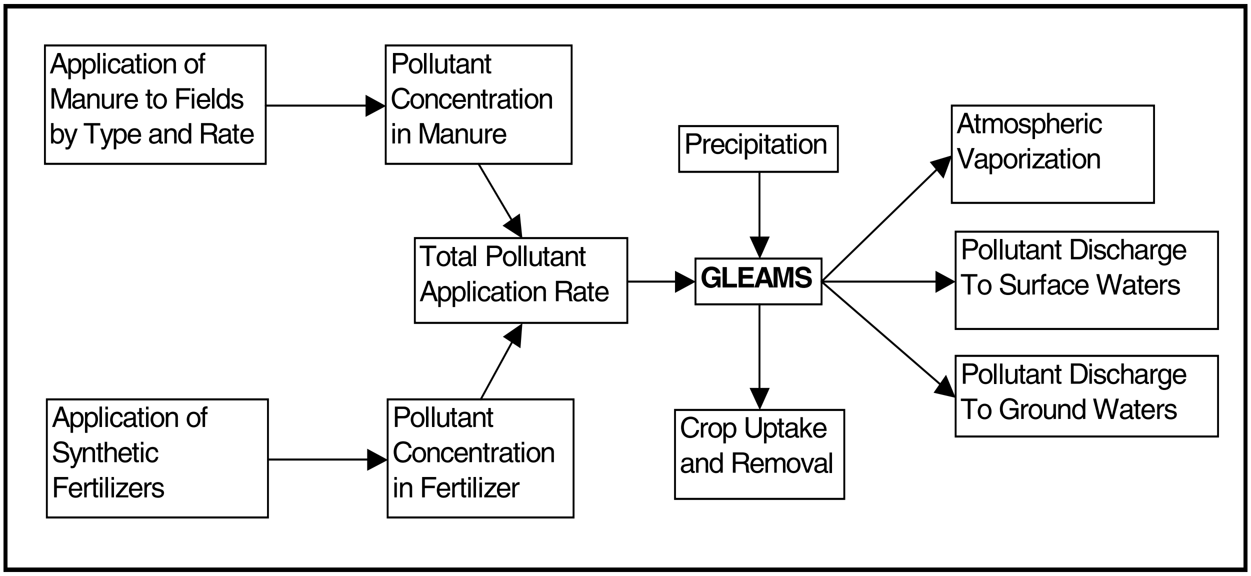


Figure 4. GLEAMS estimation of per-farm field loadings in EPA's assessment of revised AFO guidelines.

1. Runoff and Sediment Processes

The erosion and sediment yield component in GLEAMS was developed for use on a storm-by-storm basis. To simulate edge-of-field performance for Sample Farms, EPA used total daily precipitation and temperature data to indicate storm type and intensity, analyzing many years of rainfall records in a continuous simulation to represent the probable range of runoff rates. Based on runoff rates, the GLEAMS model estimates sediment discharge based on erosion and sediment transport relationships that account for field management practices, cropping systems, and regional variation in physiographic conditions (e.g., soil type and depth). As discussed below, many of the model parameters in GLEAMS were originally developed using the time-tested Revised Universal Soil Loss Equation (RUSLE) (Renard et al., 1997), based on extensive field plot tests to estimate appropriate model parameter values.

Edge-of-field sediment yield is a function of detachment of soil particles and the subsequent transport of these particles. On a given field, detachment or sediment transport capacity may be limited, depending on topography, soil characteristics, cover, rainfall/runoff rates and amounts, and land management practices. As discussed later, accounting for geographically varying soils (for locations preferred by AFO operations) was a prime factor in developing the large number of Sample Farm models. For Sample Farm models, detachment and edge-of-field transport were estimated by GLEAMS based on the following soil parameters:

- Soil erodibility factor (K)

- Cover-management factor (C)
- Support practice factor (P)
- Slope length and steepness factor (LS)
- Rainfall-runoff erosivity factor (R)

For the soils found in modeled locations, K was estimated using tabular information found in the GLEAMS manual. Erodibility is based on the soil texture, organic matter content, soil structure, and soil permeability factors, parameters that are generally available for the contiguous states. (EPA's assessment of soils on a county-by-county basis is detailed below.)

C represents the crop cover factor that enables the GLEAMS model to track and simulate seasonal changes in soil cover due to crop growth, harvest, and residue cover. EPA contacted county USDA Extension Agency personnel to identify county-specific cropping practices to serve as a basis for selecting appropriate county-specific crop rotations. P considers cropland management practices such as contouring, strip cropping, and terracing. These practices principally cause erosion by modifying the flow pattern, grade, or direction of cropland surface runoff by reducing the amount and rate of runoff. For more information on the runoff and sediment process used by GLEAMS, consult the user manual (Knisel et al., 1993).

Finally, GLEAMS accounts for the effect of topography on erosion using the LS factor (in a fashion similar to RUSLE). Erosion increases as slope length increases, and this is accounted for by the slope length factor (L). The slope steepness factor (S) reflects the influence of slope gradient on erosion. R quantifies the effect of raindrop impact and also reflects the amount and rate of runoff likely to be associated with the rain and subsequent erosion (Renard et al., 1997). EPA selected slope values for its models based on STATSGO. The length factor was assumed constant for all Sample Farms. The rainfall and runoff factor is related to the energy imposed on the soil surface from falling raindrops and is calculated within the GLEAMS routines.

When assessing potential pollutant reductions associated with the revision of current effluent guidelines, the hydrologic and erosion parameters used to run GLEAMS did not vary from baseline.

2. Nutrients

Nutrient losses in surface runoff, transported sediment, and leaching to groundwater are all represented in GLEAMS. To represent the daily movements of nutrients on a field-by-field basis, GLEAMS provides a relatively complete representation of N and P cycling. The two nutrient elements are treated in a similar fashion with respect to some of the transformations occurring in the soil. However, some obvious differences are considered, such as N fixation by legumes, denitrification, N in rainfall, ammonia volatilization from animal waste, and the two-stage mineralization of nitrate—ammonification and nitrification.

A schematic representation of the N component is shown in Figure 5 with the processes and flow directions. Figure 5 obviously demonstrates the complexity of N cycling and the wide range of nutrient forms tracked in GLEAMS. Some of the forms in Figure 5 affect surface runoff only (grain, stover, atmospheric N, and assimilated N), while others affect both surface and subsurface computational soil layers (fresh organic N in crop residue and roots; fertilizer, nitrate, ammonia, and organic N in animal waste). Finally, some nutrient forms are found only within the soil column; for example, active and stable soil N occurs only in the soil. A full description of the GLEAMS algorithm is beyond the scope of this report. EPA refers interested readers to the GLEAMS user manual and documentation (Knisel et al., 1993) for a more detailed description of the components of the N cycle.

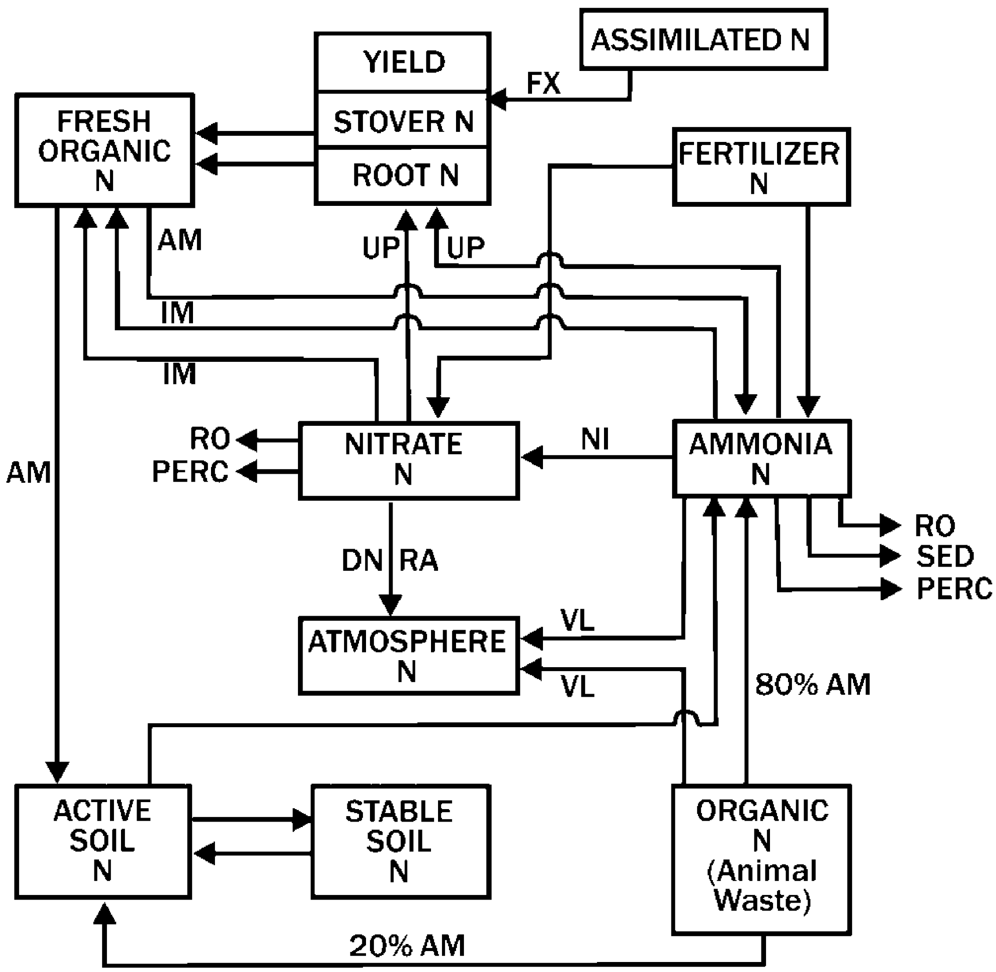


Figure 5. The nitrogen cycle as simulated by GLEAMS.
AM = ammonification; NI = nitrification; DN = denitrification; VL = volatization; IM = immobilization; UP = uptake; FX = fixation; RO = runoff; SED = sediment erosion; PERC = percolation.

A simplified P model was developed by Jones et al. (1984) and Sharpley et al. (1984) to assess long-term soil erosion and crop productivity. The model was incorporated into the EPIC model (Sharpley et al., 1990) and was successfully applied over a wide range of soils, crops, and climatic regions. Since the model represents a state-of-the-art P model, and is consistent with other components of GLEAMS, it was largely incorporated intact into the GLEAMS nutrient component. The only modification to it relates to the mineralization of organic P in animal waste. Since most of the P processes parallel those in the N component, P transformations were modeled similarly to N.

The P component is depicted in Figure 6 with the various transformations shown. The similarities with the representation of the N component can be seen by comparing Figure 5 to Figure 6. The components of the P cycle include three soil P pools: a mineralizable organic humus P pool (SORGP), an active mineral P pool (PMINP), and a long-term stable mineral P

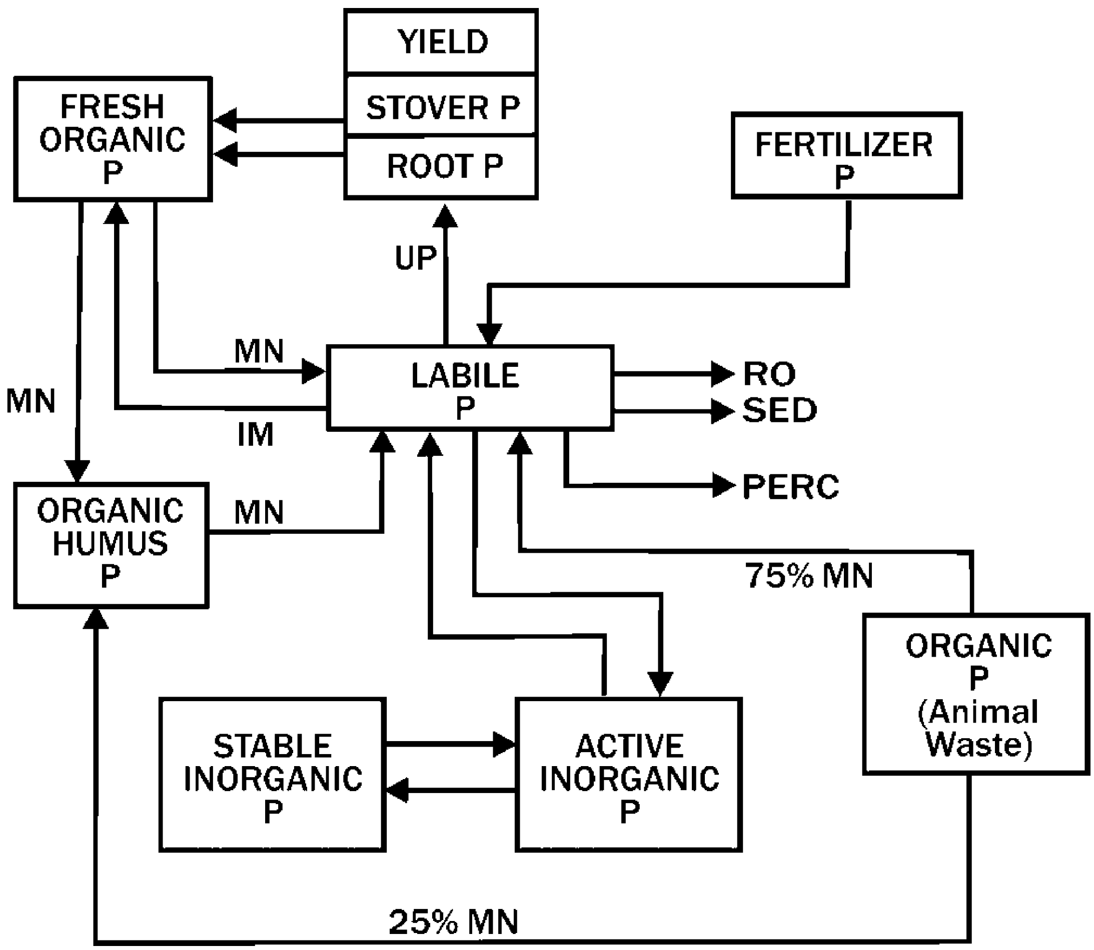


Figure 6. The phosphorus cycle as simulated by GLEAMS.
MN = mineralization; IM = immobilization; RO = runoff; SED = sediment erosion; PERC = percolation.

pool (SOILP). Analogous to the N component, a fresh organic P pool (FOP) represents the mineralizable crop root residue and surface residue (RESDP). Organic P in animal waste (ORGPW) and plant-available and mobile labile P (PLAB) are represented in the model.

3. Metals and Pathogens Processes

Few models are available to simulate the movement of metals and pathogens in the soil/plant system, and even fewer that can simultaneously meet EPA's assessment constraints and priorities. As a result, EPA elected to use GLEAMS to simulate metals and pathogen loadings from AFO facilities. To implement this approach, EPA had to adapt to the requirements of existing GLEAMS routines and data procedures aimed at fate/transport assessment of pesticides. Besides nutrients, the only other general class of pollutants GLEAMS is designed to assess is pesticides. GLEAMS data input and data parameters are not designed for other pollutant classes (e.g., polyaromatic hydrocarbons, volatile hydrocarbons, inorganic pollutants).

The capability of GLEAMS to model pesticides is extensive and reflects the influence of pesticide properties, soils, climate, and soil management. In addition, GLEAMS can represent the effects of pesticide losses in surface runoff, in transported sediments, and in percolate below the root zone. Fortunately, the variables used to describe the properties of pesticides can also be used to describe other pollutants, such as metals and pathogens in soils. However, to represent metals and pathogens, additional steps are needed to adapt data to work within existing pesticide routines. For example, the behavior of metals in soil can be represented as "pesticide" with an extremely long half-life, instead of the relatively short half-life used to describe a true pesticide. Thus, when this document refers to the pesticide module of GLEAMS, it actually refers to EPA's simulation of metals and pathogens.

A GLEAMS simulation can consider up to 10 different pesticides (metals or pathogens) applied during the simulation period. As noted in Figure 3, pollutant loadings to the surface of cropland can originate from two sources: manure and synthetic fertilizer. To simulate metals and pathogen loadings, the GLEAMS input files were set up to synchronize manure-based metal and pathogen loadings (as if they were pesticide applications) with the dates of manure application. Manure was applied prior to planting for row crops and immediately after cutting for perennial crops on Sample Farms. So EPA first estimated the metals and pathogen loadings correlated with fertilizer application (manure or synthetic), and then introduced these loadings at the proper time within the simulation.

When EPA estimated the application rate of metals and pathogens to cropland, it first estimated P application, then used the multiplication factors in Table 3 to convert P into loading for the other pollutants. To account for losses during collection, storage, and transport, EPA elected to use the P-loss coefficients presented in the approach used in the Cost Model to estimate the

Table 3. Multiplication Factors to Convert Manure Phosphorus Loadings (As Excreted) into Loadings for Other Pollutants

Manure Component	Dairy	Beef/Heifer	Veal	Swine	Layer	Broiler	Turkey
Fecal Coliform	7.66E+01	3.15E+02	1.09E+02	1.00E+02	2.50E+01	2.00E+00	6.09E+00
Fecal Streptococcus	4.47E+02	1.41E+02	6.36E+02	2.94E+03	5.33E+01	1.74E+03	1.30E+01
Zinc	1.91E-02	1.20E-02	1.97E-01	2.78E-02	6.33E-02	1.20E-02	6.52E-02
Copper	4.79E-03	3.37E-03	7.27E-04	6.67E-03	2.77E-03	3.27E-03	3.09E-03
Cadmium	3.19E-05	3.26E-05	4.55E-05	1.50E-04	1.27E-04	1.10E-04	1.19E-05
Nickel	2.98E-03	3.04E-03	4.24E-03	4.42E-04	8.33E-04	3.90E-03	2.14E-04
Lead	0.00E+00	0.00E+00	0.00E+00	4.67E-04	2.47E-03	1.38E-03	2.27E-03
Arsenic	0.00E+00	0.00E+00	0.00E+00	3.83E-03	4.57E-04	1.61E-03	2.10E-03

Source: ASAE, 2001.

percentage of total loss. This approach conservatively neglects the losses due to other conditions (e.g., volatilization). Multiplying all other pollutant loads by the percent of P loss yielded the net loss for each pollutant. For example, if P loss (due to collection, storage, and transport) for swine facilities in the Mid Atlantic Region was 5 percent, EPA assumed the loss of fecal loadings for these facilities was also 5 percent.

At the start of its assessment, EPA determined that manure alone was not the only potential source of metals loadings to cropland servicing the AFO industry. Synthetic fertilizer also contains metals (e.g., arsenic, cadmium, copper, lead, nickel, and zinc), and potential effluent guidelines revisions will affect the scope of synthetic fertilizer use. EPA performed an in-depth analysis of synthetic fertilizer to characterize fertilizer pollutant constitution. Several papers have identified metal concentrations in commercial fertilizers (Van Loon and Lichwa, 1973; Senesi et al., 1983; and Senesi et al., 1988). Senesi and Polemio (1981) provide the most detailed list of trace elements in a variety of synthetic fertilizers. In general, the highest trace element concentrations were found in fertilizers containing phosphates. Synthetic N fertilizers showed lower amounts of trace elements.

EPA also researched the variety of active agents in synthetic fertilizer. Although a number of fertilizers and fertilizer combinations might be used for cropland, urea and triple super phosphate were judged to be the most common and were selected to represent the fertilizers used for synthetically fertilized land associated with CAFOs. The metals concentrations found in these two active agents are presented in Table 4. The high- and low-end urea values show the range of metals concentrations in commercially available urea-based fertilizers.

Table 4. Trace Element Contents (mg kg^{-1}) of Two Urea and One Triple Super Phosphate Samples

	Arsenic	Cadmium	Copper	Nickel	Lead	Zinc
Fertilizer Active Agent						
Low-End Urea Estimate (46% N)	5.60	0.22	<1	7.20	5.57	1.00
High-End Urea Estimate (46% N)	33.42	3.20	1.00	10.20	48.72	<1
Mid-point Urea Estimate (46% N)	19.51	1.41	1.00	8.70	27.15	1.00
Triple Super Phosphate (46-48%)	321.55	3.25	138.00	44.20	13.92	138.00
Fertilizer As Applied						
Mid-point Urea Estimate	15.37	1.47	0.46	4.69	22.41	0.46
Triple Super Phosphate Estimate	9.17	0.66	0.47	4.09	12.76	0.47

Source: Senesi and Polemio (1981).

To simulate land application of these metals along with synthetic fertilizer, the metals concentrations were normalized to the N content for urea and to the P content for triple super phosphate. As shown in Table 4, EPA normalized by adjusting the trace element concentration by the percentage of nutrient in the sample (46 percent for urea and 47 percent for triple super phosphorus) to account for nonnutrient filler material. The end result is the metals loadings rates per pound of fertilizer, in the form used in field application.

Water solubility and adsorption or partition coefficients are required for each metal and pathogen modeled in GLEAMS. Based on a review of available literature, it was assumed that the fecal and metal components were both very soluble (compared to low-soluble materials such as pesticides). For example, the GLEAMS manual provides a description of an arsenic compound (the conjugate base of arsenate acid) whose solubility was very high. The soil-water partition coefficient agreed with those found in the *USEPA Superfund Soil Screening Guidance*. Partition coefficients for metals were also obtained from this publication (www.epa.gov/superfund/ resources/soil/toc.htm) based on a pH of 7. The adsorption or partition coefficients from the Superfund analysis are presented as soil-water partition coefficients. As mentioned above, using existing GLEAMS pesticide routines to simulate nonpesticide pollutants required data adjustment to offset model features not applicable to nonpesticide pollutants. For example, GLEAMS interprets pesticide solubility in terms of organic content, an unnecessary feature for nonpesticides. So prior to model input, EPA adjusted the metals and pathogen soil-water partition coefficients by dividing by both soil organic matter content and the estimated ratio of organic carbon to organic matter, knowing that GLEAMS would reverse these calculations at the start of its simulation. While of interest to those very familiar with the intricacies of GLEAMS, for most readers the details of these input adjustments are not as important as the fact that EPA made the necessary data adjustments to permit

GLEAMS to properly assess nonpesticide pollutants. For more information on the procedures used to simulate metals and pathogens using the pesticide subroutines, refer to the GLEAMS user manual and documentation (Knisel et al., 1993).

The suite of soil-water partition coefficients used by EPA (prior to any adjustment to adapt them for GLEAMS) is presented in Table 5. These coefficients are important because they establish the ratio of pollutant attached to particulate matter (e.g., adsorbed onto a soil particle) to that dissolved in either runoff or leaching groundwater. The partitioning of pollutants is necessary to track the fate and transport of pollutants once they arrive on farm fields.

For the continuous simulations performed by EPA, natural reduction in pollutant concentration must be estimated. In other words, GLEAMS must estimate what fraction of pollutants retained on fields today will be present at the end of the next day. To meet this requirement, GLEAMS has a pollutant dissipation or degradation rate. EPA assumed degradation rates obey first order kinetics as described by published pollutant half-life information (Coyne et al., 1996). The half-life is the amount of time it takes for half of the contaminant to dissipate (or be destroyed). Half-life is applicable only to pathogens as metals are conservative in nature (i.e., they are not biodegradable and do not die off).

Table 5. Soil-Water Partition Coefficients for Pathogens and Metals Used in GLEAMS

Element	Soil-Water Partition Coefficient (liters/kg)
Fecal Coliform[1]	360
Fecal Streptococcus[1]	360
Zinc	62
Copper	360
Cadmium	75
Nickel	65
Lead[1]	360
Arsenic	29

Source: *USEPA Superfund Soil Screening Guidance* <www.epa.gov/superfund/resources/soil/index.htm>.
[1]No soil-water partition coefficient was available, so based on anecdotal information it was assumed that the bacterium and lead behave similarly to copper.

The two pathogens evaluated by EPA in its AFO analysis were fecal coliform and fecal streptococcus. As indicator pathogens, these bacteria suggest the scope of, but not the entirety of, the potential problems associated with active biological agents (e.g., all bacteria, protozoan, and virus). As shown in Table 3, however, both pathogens are present in manure and sufficient literature exists to characterize their behavior in the environment. (Note, by evaluating only these two pathogens to gauge the potential benefits of rule revision, EPA acknowledges it is probably underestimating the total true benefits.) The literature suggests that both fecal coliform and fecal streptococcus degrade rapidly in the soil system. Research by Coyne et al. (1996) found background concentrations on manured cropland for fecal coliform and fecal streptococcus to be near zero and insignificant. Other factors important for simulating pathogens is their persistence in the environment. Coyne et al. (1996) measured the time needed to reduce fecal coliform populations by 50 percent and found these values to be between 5.8 and 7.7 days.

Literature suggests that varying manure application rates may have an impact on the half-lives of pathogens, but the actual viability also depends on temperature, ultraviolet (UV) exposure, method of land application, moisture, and competition with soil microorganisms. At the start of simulation with its 13,500 Sample Farm models, EPA assumed field bacteria concentrations were zero and varied bacteria half-life based on manure application rates. Research conducted by USDA suggests a correlation between P and fecal coliform concentrations in field runoff, a relationship that also reflects the influence of varying manure application rates (Sadeghi, 2002). Under greater than N-based (baseline), N-based, and P-based application rates, EPA set the pathogen half-life at 7.9, 7.7, and 7.5 days, respectively, to reflect a modest 3 percent change in viability due to application rate.

Before any simulations of metals and pathogen loading could begin, background concentrations in the soil had to be determined. Initial conditions for background concentrations of zinc, cadmium, nickel, and lead in U.S. soils as obtained from the literature are presented in Table 6. As discussed later, EPA's simulation period for estimating edge-of-field pollutant loadings under baseline and option conditions was 25 years. However, EPA's total simulation period with GLEAMS spanned a total of 50 years. The first 25 years of simulation with continuous daily precipitation started with the initial concentrations shown in Table 6, but the GLEAMS simulation adjusted the soil concentration from that point forward. EPA used the 25-year "start-up" period to permit each Sample Farm model to stabilize into its own local equilibrium prior to use in estimating edge-of-field pollutant loadings.

Table 6. National Background Concentrations of Pollutants in U.S. Soil

Chemical	Number of Samples	Median Soil Concentration (ug/g)
Zinc[a]	3,325	54.0
Copper[b]	n/a	25.8
Cadmium[a]	3,325	0.2
Nickel[a]	3,325	18.0
Lead[a]	3,325	12.0
Arsenic[c]	16	3.0

Sources: a, Holmgren et al., 1992; b, Salomons and Forstner, 1984, c, Baxter et al., 1983.

III. Sample Farm Definition

EPA's process for selecting a suite of Sample Farms for edge-of-field (GLEAMS) modeling was based on the following criteria:

- To represent top-producing areas in the nation (i.e., geographic regions preferred by AFOs).
- To reflect geographic preferences for industry sectors.
- To account for geographic variation in climate.
- To represent the array of farm sizes, farm types and farm operations.
- To make the maximum use of available data from standardized and peer-reviewed data sources.

Based on these criteria, EPA believes its suite of Sample Farms appropriately characterizes and then parameterizes the industry, and reasonably represents industry activities and conditions. As detailed below, EPA based much of its assessment on farm and physical conditions found in the top-producing counties within the top-producing states, while taking additional steps to ensure all geographic regions were represented. In all cases, EPA's procedure relied on published production numbers of the 1997 Census of Agriculture (USDA, 1999) for each of 10 sectors, namely: Broilers, Layers/Pullets, Beef Cattle, Hogs and Pigs or Swine, Milk or Dairy Cows, and Turkeys. For all regulatory conditions, annual production numbers were held as constants (i.e., farm populations and total production do not change with time or in response to EPA's effluent guidelines).

To provide an overview of EPA's assessment, Table 7 details the number of Sample Farm simulations. The 13,500 simulations listed in Table 7 represent baseline conditions and conditions expected under each of six postrevision conditions. EPA's rationale for setting the number of Sample Farm simulations and characterizing different farm conditions are described in this section, following the order presented in Table 7.

It should be stated that total farm or facility loadings are made up of three components:

1. Edge-of-field loadings for acres receiving land applied manure
2. Direct feedlot loadings for open-air feedlot footprints
3. Loadings from leaking lagoons.

This section details EPA's modeling approaches to each of these three load types.

Table 7. Total Number of Sample Farm Simulations (GLEAMS Model Runs)

Sector	Locations	Size Groups	Manure Application Methods	Manure Application Rates	Soil Types	Number of Simulations
Beef	10	5	2	6	3	1,800
Broiler	10	5	2	6	3	1,800
Dairy	10	4	2	6	3	1,440
Heifer	5	4	2	6	3	720
Layer (dry)	10	5	2	6	3	1,800
Layer (wet)	5	2	2	6	3	360
Swine (finishing)	10	5	2	6	3	1,800
Swine (farrow-to-finish)	10	5	2	6	3	1,800
Turkey	10	4	2	6	3	1,440
Veal	5	3	2	6	3	540
Total	5 or 10	42	2	6	3	13,500

A. Selection of Representative Farm Locations

Figure 7 shows the delineated geographic regions that encompass the groups of states used in EPA's CAFO analysis. See the Cost Report for additional information on how these modeling regions were established. EPA's purpose for defining geographic regions was to help ensure that all geographic regions are represented in its industry characterization, not just the top-producing areas. For each region in Figure 7, EPA reviewed each state's total production rate for each sector (e.g., the number of milk cows) to identify the state with the highest production. These highest ranking states are listed in Table 8 by sector and region.

In addition to each region's highest producing state, EPA also identified, independent of the regions, each sector's five highest ranking states for inclusion in its assessment. In general, this two-part selection process produced a list of 10 states for each sector for EPA to prioritize data collection and modeling. EPA's intent for developing Sample Farm models for each of these states is to represent the majority of production while simultaneously ensuring that each region has at least one state as its representative.

The final selection of states by sector is shown in Tables 9 through 14, along with an indication of which states are regional and national top producers. In summary, the priority states in these tables represent between 64 and 87 percent of the national total production, depending on the sector. In addition, the tables show the national ranking of each state and indicate several cases where a state was represented by a sector-specific Sample Farm model despite a low national ranking in production. Note that Florida was also modeled for the beef and dairy sectors to better correlate with the regions modeled in the costing analysis.

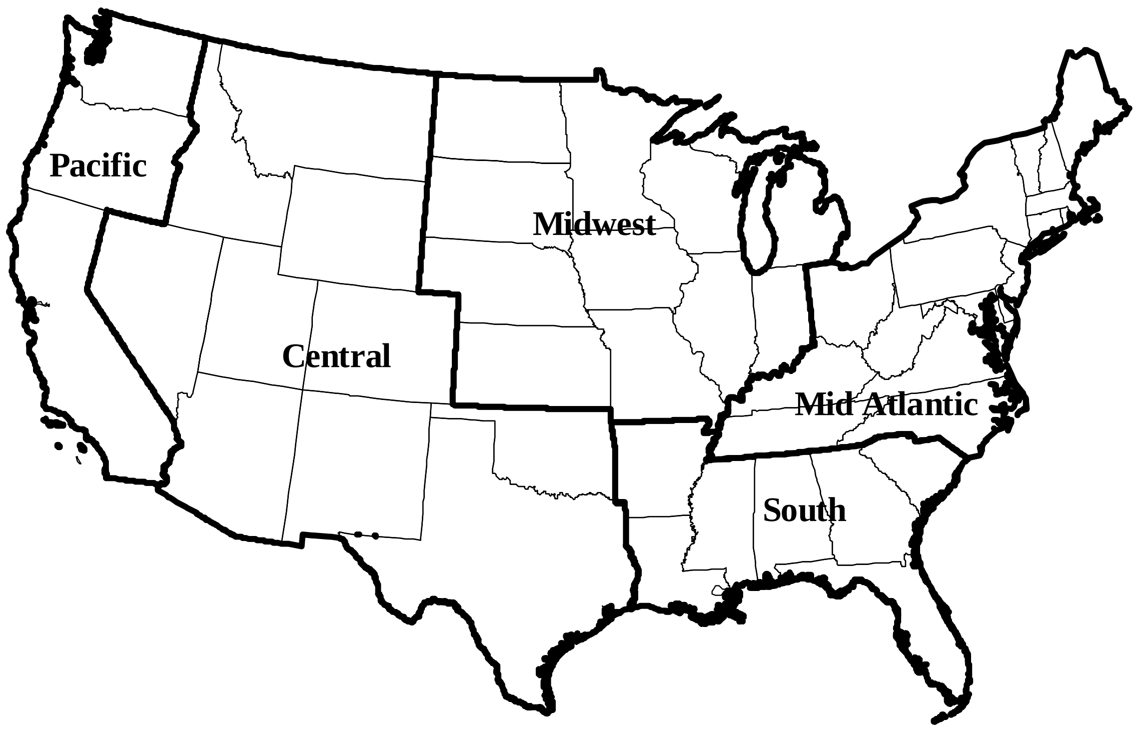


Figure 7. State distributions into the various regions used to model CAFO pollutant loading reductions.

Table 8. Top Producing States by Sector for Each Region

Region	Broilers (total)	Layers/ Pullets (total)	Cattle/ Beef (total)	Hogs and Pigs (total)	Milk Cows (total)	Turkeys (total)
Mid Atlantic	North Carolina (106,156,781)	Pennsylvania (27,856,467)	Pennsylvania (169,782)	North Carolina (9,624,860)	New York (700,480)	North Carolina (17,834,117)
South	Arkansas (66,603,544)	Georgia (21,525,495)	Arkansas (27,795)	Arkansas (858,741)	Florida (159,614)	Arkansas (9,333,308)
Midwest	Missouri (30,254,497)	Ohio (29,023,796)	Kansas (5,282,661)	Iowa (14,651,919)	Wisconsin (1,336,626)	Minnesota (16,220,257)
Central	Texas (66,603,544)	Texas (20,184,249)	Texas (6,056,726)	Oklahoma (1,689,700)	Texas (374,816)	Texas (5,354,160)
Pacific	California (34,781,220)	California (34,149,987)	California (790,9630)	California (212,088)	California (1,403,217)	California (8,633,371)

Source: USDA, 1999

Table 9. Top 10 States Including at Least 1 from Every AFO Region, Broilers, 1997

State	1997 Broilers Inventory	National Ranking	AFO Region	Regional Top Producer	National Top 10 Producer
Arkansas	172,617,806	1	South	Yes	Yes
Georgia	149,740,420	2	South		Yes
Alabama	134,027,304	3	South		Yes
North Carolina	106,156,781	4	Mid Atlantic	Yes	Yes
Mississippi	94,551,890	5	South		Yes
Texas	66,603,544	6	Central	Yes	Yes
Maryland	45,227,080	7	Mid Atlantic		Yes
Virginia	41,360,070	8	Mid Atlantic		Yes
California	34,781,220	10	Pacific	Yes	Yes
Missouri	30,254,497	11	Midwest	Yes	
Totals	875,322,609				

Note: Annual total national production for this sector is approximately 1.1 billion, so selected states represent 79 percent of national total production.

Table 10. Top 10 States Including at Least 1 from every AFO Region, Layers and Pullets, 1997

State	1997 Layers and Pullets Inventory	National Ranking	AFO Region	Regional Top Producer	National Top 10 Producer
California	34,149,987	1	Pacific	Yes	Yes
Ohio	29,023,796	2	Midwest	Yes	Yes
Pennsylvania	27,856,467	3	Mid Atlantic	Yes	Yes
Iowa	24,876,834	4	Midwest		Yes
Indiana	22,731,425	5	Midwest		Yes
Georgia	21,525,495	6	South	Yes	Yes
Arkansas	20,213,603	7	South		Yes
Texas	20,184,249	8	Central	Yes	Yes
North Carolina	16,162,563	9	Mid Atlantic		Yes
Alabama	13,432,845	10	South		Yes
Totals	230,159,261				

Note: Annual total national production for this sector is approximately 362 million, so selected states represent 64 percent of national total production.

Table 11. Top 10 States Including at Least 1 from every AFO Region, Beef, 1997

State	1997 Cattle Fattened on Grain and Concentrates Sold	National Ranking	AFO Region	Regional Top Producer	National Top 10 Producer
Texas	6,056,726	1	Central	Yes	Yes
Kansas	5,282,661	2	Midwest	Yes	Yes
Nebraska	4,851,246	3	Midwest		Yes
Colorado	2,432,312	4	Central		Yes
Iowa	1,646,477	5	Midwest		Yes
Oklahoma	958,192	6	Central		Yes
California	790,963	7	Pacific	Yes	Yes
Idaho	632,606	8	Central	Yes	Yes
Pennsylvania	169,782	20	Mid Atlantic		Yes
Florida *	5,922	40	South		
Totals	22,826,887				

Note: Annual total national production for this sector is approximately 27 million, so selected states represent 84 percent of national total production.

Table 12. Top 10 States Including at Least 1 from every AFO Region, Hogs and Pigs, 1997

State	1997 Total Hogs & Pigs Inventory	National Ranking	AFO Region	Regional Top Producer	National Top 10 Producer
Iowa	14,651,919	1	Midwest	Yes	Yes
North Carolina	9,624,860	2	Mid Atlantic	Yes	Yes
Minnesota	5,722,460	3	Midwest		Yes
Illinois	4,679,166	4	Midwest		Yes
Indiana	3,972,060	5	Midwest		Yes
Missouri	3,546,972	6	Midwest		Yes
Nebraska	3,452,386	7	Midwest		Yes
Oklahoma	1,689,700	9	Central	Yes	Yes
Arkansas	858,741	14	South	Yes	
California	212,088	25	Pacific	Yes	
Totals	48,412,349				

Note: Annual total national production for this sector is approximately 61 million, so selected states represent 79 percent of national total production.

Table 13. Top 10 States Including at Least 1 from every AFO Region, Dairy cows 1997.

State	1997 Milk Cows Inventory	National Ranking	AFO Region	Regional Top Producer	National Top 10 Producer
California	1,403,217	1	Pacific	Yes	Yes
Wisconsin	1,336,626	2	Midwest	Yes	Yes
New York	700,480	3	Mid Atlantic	Yes	Yes
Pennsylvania	621,530	4	Mid Atlantic		Yes
Minnesota	541,650	5	Midwest		Yes
Texas	374,816	6	Central	Yes	Yes
Michigan	300,641	7	Midwest		Yes
Idaho	265,854	8	Central		Yes
Ohio	262,834	9	Midwest		Yes
Florida	159,614	15	South	Yes	
Totals	5,969,259				

Note: Annual total national production for this sector is approximately 9.1 million, so selected states represent 66 percent of national total production.

Table 14. Top 10 States Including at Least 1 from every AFO Region, Turkey, 1997

State	1997 Turkeys Inventory	National Ranking	AFO Region	Regional Top Producer	National Top 10 Producer
North Carolina	17,834,117	1	Mid Atlantic	Yes	Yes
Minnesota	16,220,257	2	Midwest	Yes	Yes
Arkansas	9,333,308	3	South	Yes	Yes
California	8,633,371	4	Pacific	Yes	Yes
Virginia	8,175,875	5	Mid Atlantic		Yes
Missouri	7,654,431	6	Midwest		Yes
Texas	5,354,160	7	Central	Yes	Yes
Indiana	4,758,760	8	Midwest		Yes
South Carolina	4,570,676	9	South		Yes
Pennsylvania	3,286,441	10	Mid Atlantic		Yes
Totals	85,823,393				

Note: Annual total national production for this sector is approximately 98 million, so selected states represent 87 percent of national total production.

In each priority state, EPA developed Sample Farm models based on farm and physical conditions found in the top-producing county. Tables provided in Appendix A show the top-producing counties identified within the 10 top-producing states, states used by EPA to estimate the aggregate regional Sample Farm performance.

B. Farm Size Classification

Table 15 presents the size distribution of CAFO facilities used by EPA to represent the industry for the 9 sectors evaluated. EPA based its size distribution on values provided by USDA's NRCS, based on the 1997 Census of Agriculture data (USDA, 2002). It should be noted that USDA estimates were for different size groupings than those in Table 15 for some sectors. EPA incorporated data from USDA's National Agricultural Statistics Service to establish its groupings. The number and percentage of farms cited in each of the size categories presented in Table 15 can be found in the Cost Methodology Report for Animal Feeding Operations. This reference also indicates the regional density of these sector size classes.

EPA believes the sector-specific farm size groupings are sufficient to characterize industry activities. Actual head counts used for each of the beef, dairy, heifer, and veal size ranges were taken from the Cost Model. Head counts for the swine and poultry sectors were based on queries of data found in the 1997 Census of Agriculture (USDA, 1999) and are presented in Table16.

Table 15. Size Classes for Model Farms Based on Number of Head

Animal Type	Medium 1	Medium 2	Medium 3	Large 1	Large 2
Beef	300-499	500-749	750-999	1,000-7,999	≥8,000
Heifer	300-499	500-749	750-999	≥1,000	NA
Dairy (Mature Dairy Cows)	200-349	350-524	525-699	≥700	NA
Veal	300-499	500-749	≥750	NA	NA
Swine	750-1,249	1,250-1,874	1,875-2,499	2,500-4,999	≥5,000
Dry Layers	25,000-49,999	50,000-74,999	75,000-81,999	82,000-599,999	≥600,000
Wet Layers	NA	NA	9,000-29,999	≥30,000	NA
Broilers	37,750-49,999	50,000-74,999	75,000-124,999	125,000-179,999	≥180,000
Turkeys	16,500-27,499	27,500-41,249	41,250-54,999	≥55,000	NA

NA = not applicable.

Table 16. Regional Head Counts Used in the Pollutant Loading Analysis

Operation	Region	Medium 1	Medium 2	Medium 3	Large 1	Large 2
Broiler	Central	39,384	58,391	89,902	140,194	372,442
Broiler	Mid Atlantic	39,787	57,118	87,708	135,705	314,411
Broiler	Midwest	39,350	58,134	87,653	160,372	559,127
Broiler	Pacific	39,532	55,645	85,494	178,985	654,274
Broiler	South	39,387	57,496	88,371	132,327	301,586
Swine-combined	Central	897	1,400	1,944	2,500	6,538
Swine-combined	Mid Atlantic	887	1,359	1,887	2,664	7,838
Swine-combined	Midwest	870	1,331	1,897	2,505	5,927
Swine-combined	Pacific	879	1,361	1,890	2,500	7,020
Swine-combined	South	898	1,402	1,947	2,500	6,511
Swine-slaughter	Central	897	1,400	1,944	2,500	6,538
Swine-slaughter	Mid Atlantic	887	1,359	1,887	2,664	7,838
Swine-slaughter	Midwest	870	1,331	1,897	2,505	5,927
Swine-slaughter	Pacific	879	1,361	1,890	2,500	7,020
Swine-slaughter	South	898	1,402	1,947	2,500	6,511
Layer	All	36,068	61,734	78,546	291,153	856,368
Layer (Wet)	All			19,500	146,426	
Turkey	All	22,246	34,640	47,534	127,396	

C. Characterization of Sample Farm Climates

For each AFO sector, the climate in the top-producing county was used to characterize state wide farm performance. EPA selected the closest meteorologic station available from approximately 1,000 locations dispersed nationally. For its assessment, EPA obtained climate data using the CLIGEN program, which is a synthetic climate generator that has been widely used by the Water Erosion Prediction Project (WEPP, Foster and Lane, 1987); EPIC; the Simulator for Water Resources in Rural Basins (SWRRB, Williams et al., 1985; Arnold et al., 1990) and several other models. This program has been well tested in many locations throughout the United States (Nicks, 1985). CLIGEN uses 25 or more years of precipitation and temperature historical climate data from the National Climatic Data Center to generate climatic databases for model simulation purposes (Nicks et al., 1995). For a user-selected time period, the CLIGEN program creates a climate database containing simulated or synthetic precipitation (i.e., precipitation that *could* happen) based on historic data and climatic trends.

The climate data required to run the GLEAMS model include precipitation, minimum and maximum air temperature, solar radiation, wind speed, and dew point temperature. Except for precipitation, EPA used the long-term monthly averages of the climatic parameters in its suite of Sample Farm models (e.g., 12 values for each parameter for each station).

D. Characterization of Sample Farm Soils

EPA's three modeled soil types correspond with the three most common soils located in agriculture land areas. The countywide performance was based on the weighted performance (based on relative frequency) of the three most common soils. To prepare for its independent assessment of each sector, EPA performed extensive evaluation of geographically linked soil data, using Geographic Information System (GIS) spatial analysis tools. Note that many of the spatial analysis details are beyond the scope of this document, and readers are referred to ESRI's Arc/View users manual for additional information on this topic.

EPA's GIS spatial analysis used two datasets in conjunction—the NRCS STATSGO dataset and the USGS Land Use and Land Cover (LULC) dataset in GIRAS (Geographic Information Retrieval Analysis System) format. These national geographic databases are widely used because they provide both uniform high quality information for the contiguous states and sufficient detail to permit a county-by-county assessment. As shown by the classifications in Table 17, the USGS LULC data files describe the vegetation, water, natural surface, and cultural features on the land surface. The LULC data were developed from manual interpretation of aerial photographs and earlier land use maps and field surveys and were then digitized. All LULC features depict the actual boundary of an area, commonly referred to as a polygon. The arcs and nodes of the polygon are further defined by a single X and Y point, or string of X-Y points that provide direction and location for the polygon. The attributes for the polygons refer to Anderson Level II LULC codes as below.

Table 17. GIRAS (Anderson Level II) Land Use Classification

Primary Classification	Secondary Classification
1 Urban or Built-Up Land	11 Residential, 12 Commercial Services, 13 Industrial, 14 Transportation and Communications, 15 Industrial and Commercial, 16 Mixed Urban or Built-Up Land,17 Other Urban or Built-Up Land
2 Agricultural Land	21 Cropland and Pasture, 22 Orchards, Groves, Vineyards, and Nurseries, 23 Confined Feeding Operations, 24 Other Agricultural Land
3 Rangeland	31 Herbaceous Rangeland, 32 Shrub and Brush Rangeland, 33 Mixed Rangeland
4 Forest Land	41 Deciduous Forest Land, 42 Evergreen Forest Land, 43 Mixed Forest Land
5 Water	51 Streams and Canals, 52 Lakes, 53 Reservoirs, 54 Bays and Estuaries
6 Wetland	61 Forested Wetland, 62 Nonforested Wetland
7 Barren Land	71 Dry Salt Flats, 72 Beaches, 73 Sandy Areas other than Beaches, 74 Bare Exposed Rock, 75 Strip Mines, Quarries, and Gravel Pits, 76 Transitional Areas, 77 Mixed Barren Land
8 Tundra	81 Shrub and Brush Tundra, 82 Herbaceous Tundra, 83 Bare Ground, 84 Wet Tundra, 85 Mixed Tundra
9 Perennial Snow and Ice	91 Perennial Snowfields, 92 Glaciers

Source: Anderson, et. al. 1976

In its spatial analysis, EPA clipped or electronically isolated LULC Classification data for top-producing counties (i.e., counties representing the top-producing states). For the CAFO analysis, only areas classified as agricultural land were selected (Land Use Codes 20 through 39). The agricultural land area was then spatially overlaid with STATSGO polygons, resulting in a tabular summary of all agricultural areas residing in the key counties.

The STATSGO dataset is a digital general soil association map consisting of digital map data and computerized attribute data. STATSGO is developed by the National Cooperative Soil Survey (NCSS) and distributed by the NRCS (formerly the Soil Conservation Service) of the USDA. The map data are collected in 1- by 2-degree topographic quadrangle units and merged and distributed as statewide coverages. STATSGO was originally developed by digitizing soil map unit delineations, which were in turn developed from detailed field surveys of soils. In its fully processed state, the STATSGO dataset consists of vector format polygons of map units. The map unit is the smallest spatial entity mapped within the STATSGO dataset, and the dataset contains 10,498 map units within the conterminous United States. Each map unit is uniquely identified with a map unit identification code (MUID).

A map unit is a collection of areas defined in terms of similar patterns of soils and/or nonsoil areas. One or more individual areas (polygons) can be labeled with a given. Each map unit consists of up to 21 components. Components are used to apportion different characteristics of a map unit and do not represent a separate spatial entity. The specific locations of components within the MUID are not spatially defined in the database. The percent composition of the map unit components or soil series represents the estimated areal proportion of each component within the STATSGO map unit. The soil components within a given MUID contain information such as soil series, organic matter, pH, and slope. Thus, several components may contain the same soil series, with variations in other parameters that distinguish them from one another.

Each component is further delineated into a maximum of six layers corresponding to distinct soil layers. Soil characteristics recorded for a layer typically consist of a high and low value, which describes a range for that characteristic within that layer. Included among the characteristics of the soil layer is the thickness of the layer.

To arrive at a robust estimate of the most prevalent soil series in the agricultural areas located by the LULC coverage, the soil map units are linked to attributes in the Map Unit Interpretations Record relational database, which gives the proportionate extent of the component soils and their properties. This consists of the STATSGO Component (STATSGOC) attribute table and the STATSGO Layer (STATSGOL) attribute table. A full record of the STATSGO data can be obtained from the Load Model CD-ROM available in the docket.

The MUID value of these selected map units is associated with the STATSGOC attribute table, (listing components of each MUID) so that every component or soil series that occurs in the agricultural land of that county is isolated and collected into a file for subsequent analysis. Proportional representation of the component is derived by multiplying the percentage of the MUID in the agricultural land by the percentage of each component. This results in an accurate tabulation of the total weighted area of each component within the agricultural land of the county.

For each MUID representing agricultural areas within surveyed counties, the top 10 (soil) components by weighted area are selected. This selected component table is linked in the GIS with the STATSGOL (layered) attribute table. The selected component table is joined to the layer table, resulting in a full attribute description (e.g., texture, pH, slope, soil erodibility) of the most common soils in the agricultural areas of the entire county (see Figure 8).

C19 = BRUNO

	A	B	C	D	E	F	G	H	I	J	K
1	Muid	Muidseqnum	Compname	Agarea	Layernum	Laydepl	Laydeph	Texture1	Texture2	Texture3	Kfact
2	TX213	TX213 1	GRUVER	0.24	1	0	8	L			0.32
3	TX213	TX213 1	GRUVER	0.24	2	8	52	CL			0.32
4	TX213	TX213 1	GRUVER	0.24	3	52	80	CL			0.32
5	TX512	TX512 1	SHERM	2.214	1	0	5	SICL			0.37
6	TX512	TX512 1	SHERM	2.214	2	5	35	C	SIC		0.37
7	TX512	TX512 1	SHERM	2.214	3	35	80	CL	C	SIC	0.37
8	TX512	TX512 8	ULYSSES	0.656	1	0	10	CL			0.32
9	TX512	TX512 8	ULYSSES	0.656	2	10	30	SIL	SICL		0.43
10	TX512	TX512 8	ULYSSES	0.656	3	30	60	SIL	L		0.43
11	TX512	TX512 9	DARROUZETT	0.615	1	0	6	CL			0.32
12	TX512	TX512 9	DARROUZETT	0.615	2	6	75	SICL	CL	C	0.37
13	TX512	TX512 9	DARROUZETT	0.615	3	75	80	SICL	CL	C	0.37
14	TN234	TN234 1	ROBINSONVILLE	7.14	1	0	7	SIL			0.32
15	TN234	TN234 1	ROBINSONVILLE	7.14	2	7	70	SR-	FSL	LFS	0.32
16	TN234	TN234 2	COMMERCE	8.33	1	0	10	SICL			0.37
17	TN234	TN234 2	COMMERCE	8.33	2	10	36	SICL	SIL	L	0.32
18	TN234	TN234 2	COMMERCE	8.33	3	36	60	SR-	VFSL	SIC	0.37
19	TN234	TN234 3	BRUNO	1.19	1	0	9	SIL			0.28
20	TN234	TN234 3	BRUNO	1.19	2	9	42	LS	LFS	S	0.15
21	TN234	TN234 3	BRUNO	1.19	3	42	60	S			0.1
22	TN234	TN234 4	TUNICA	2.38	1	0	7	C			0.32
23	TN234	TN234 4	TUNICA	2.38	2	7	28	C	SIC		0.32
24	TN234	TN234 4	TUNICA	2.38	3	28	48	FSL	L	SICL	0.32
25	TN234	TN234 5	CREVASSE	2.856	1	0	10	LFS			0.1
26	TN234	TN234 5	CREVASSE	2.856	2	10	60	S	LS	LFS	0.15
27	TN234	TN234 6	SHARKEY	1.904	1	0	9	C			0.32
28	TN234	TN234 6	SHARKEY	1.904	2	9	42	C			0.28
29	TN234	TN234 6	SHARKEY	1.904	3	42	60	C	SICL	SIL	0.28

Figure 8. Examples of the top are-weighted soil components along with layer attribute information in a county.

From its multi-step assessment of soils, EPA was able to isolate the three most common soils in the top-producing counties. Soil features and data for these soils provide the parameters needed in EPA's Sample Farm models (i.e., needed by GLEAMS).

The soil parameters required by the GLEAMS model that are directly or partially derived from the STATSGO database include permeability, soil porosity, field capacity, permanent wilting point, organic matter content, percent clay, percent silt, and evaporation. Table 18 shows which STATSGO parameters are used as input parameters for the GLEAMS model. Low and high estimates of some selected parameters are also provided in the STATSGO database. To obtain a value for input into GLEAMS, the arithmetic average of the high and low values was calculated for every soil layer.

The STATSGO database also provides the hydrologic soil group. Along with other parameters such as the land use/practice, hydrologic condition, and antecedent soil moisture, the hydrologic soil group parameter is used to estimate the surface runoff curve number (CN). To establish a starting value for Sample Farm simulations, the initial CN was estimated by assuming an average antecedent moisture condition of II (CN2) for the various cropping practices. In summary, EPA's approach uses the soil attributes of most common soils in agricultural land areas for top-producing counties to indicate the most probable conditions found in farms affected by industry activities.

Table 18. STATSGO Soil Parameters

Soil Parameters	STATSGO parameter	GLEAMS Relationship
Soil Permeability (P)	Perm, Permeability Rate	P = Perm
Soil Porosity (Por)	BD, Bulk density	Por = 1 – BD/2.65
Permanent Wilting Point (PWP)	Texture, Soil Textural Class	PWP values obtained from literature based on soil textural class
Field Capacity (FC)	Available Water Capacity	FC = AWC + PWP
Organic Matter Content (OM)	Organic Matter (Om)	OM = Om
Percent Clay (%C)	Clay, Percent Clay	%C = Clay
Percent Silt (%Si)	no200, Percent Passing Sieve No. 200	%SI = no200 minus %C
Surface Evaporation Constant (CONA)	Surftex, Surface Soil Texture	CONA values obtained from literature based on surface soil texture

E. Sample Farm Cropping System

Cropping systems establish general (typical) relationships among crop rotation, crop yield, and nutrient requirements. To determine which cropping systems are used most commonly in agricultural land, cropping system patterns were requested from USDA State Extension personnel for top-producing counties (see Appendix D). In addition, crop yields, planting, and harvesting dates were researched based on USDA publications (USDA, 1997). EPA obtained typical crop yields value from the *Agricultural Waste Management Field Handbook* (See Table 19). County rotation data are summarized in Tables 20 through 26. EPA used the combination of these two datasets to establish probable farm behavior and to set farm features required in the Sample Farms models.

Average annual N and P removal rates were calculated based on the yields and nutrient removal rates presented in Table 19. For example, alfalfa yields 4 tons (8,000 pounds) per acre and contains 2.25 percent N for a total of 180 pounds of N in the harvested material. However, following the procedures of USDA (2000b) only 70 percent of the N is available in manure for crop uptake. Thus, the N removal (180 pounds per acre) was divided by 70 percent for an adjusted N removal rate of 257 pounds per acre. When considering cropping patterns in Tables 20 through 26, the average annual yields were further refined based on the rotational sequence. For example, beef operations in Cassia, Idaho, in the Central Region (Table 20) had a 5-year rotation. EPA assumed 4 years of continuous alfalfa followed by 1 year of alfalfa. The average N removal was calculated by multiplying the nutrient removal per crop per year by the number

of years in the rotation and was summed for each crop. The total N uptake per acre over the 5-year rotation is 1,248 pounds of N ([4 years of alfalfa × 257 pounds N] + [1 year of silage × 220 pounds N]). Dividing the rotation's entire N removal by the rotation length (5 years) results in an annual N removal of 250 pounds per year. The method used to determine P is similar to that of N except that the removal is not adjusted by 70 percent as is done with N.

Table 19. Typical Yields and Nutrient Uptake Used to Determine Pollutant Loading Reductions.

Crop	Typical Yield	Yield Unit per Acre	Nitrogen Removed (percent)	Phosphorus Removed (percent)	Nitrogen Removal (lb/ac)	Phosphorus Removal (lb/ac)
Alfalfa	4	tons	2.25	0.22	257	18
Bermuda grass	8	tons	1.88	0.19	430	30
Corn	6,720	lb	1.61	0.28	155	19
Oats	2,560	lb	1.95	0.34	71	9
Orchard Grass	6	tons	1.47	0.20	252	24
Rye	1,680	lb	2.08	0.26	50	4
Silage	7	tons	1.10	0.25	220	35
Sorghum	6	tons	1.44	0.19	247	23
Soybean	2,100	lb	6.25	0.64	188	13
Wheat	2,400	lb	2.08	0.62	71	15

Table 20. Typical Crop Rotations and Annual Nutrient Removal Rates for Beef Operations.

Sector	Region	County	State	FIPS	Crops	Years in Rotation	N (lb/ac)	P (lb/ac)
Beef	Central	Cassia	ID	16031	Alfalfa/silage	5	250	21
Beef	Central	Deaf Smith	TX	48117	Silage/wheat	1	292	50
Beef	Central	Texas	OK	40139	Silage/orchard	1	472	59
Beef	Central	Weld	CO	08123	Silage/wheat	1	292	50
Beef	Mid Atlantic	Lancaster	PA	42071	Alfalfa/silage	3	245	23
Beef	Midwest	Cuming	NE	31039	Alfalfa/silage	5	250	21
Beef	Midwest	Scott	KS	20171	Alfalfa/silage	5	250	21
Beef	Pacific	Imperial	CA	06025	Alfalfa/silage/oats	2	275	31
Beef	South	Marion	AR	05089	Bermuda grass	1	272	34
Beef	South	Marion	FL	12083	Orchard/silage/oats	2	430	30

Table 21. Typical Crop Rotations and Annual Nutrient Removal Rates for Broiler Operations

Sector	Region	County	State	FIPS	Crops	Years in Rotation	N (lb/ac)	P (lb/ac)
Broiler	Central	Shelby	TX	48419	Bermuda grass	1	430	42
Broiler	Mid Atlantic	Rockingham	VA	51165	Corn/wheat/ soybean	2	207	24
Broiler	Mid Atlantic	Wicomico	MD	24045	Corn/wheat/soybean	2	207	24
Broiler	Mid Atlantic	Wilkes	NC	37193	Bermuda grass	1	430	30
Broiler	Midwest	Barry	MO	29009	Soybean/corn	2	171	16
Broiler	Pacific	Fresno	CA	06019	Alfalfa/silage/oats	2	275	31
Broiler	South	Benton	AR	05007	Bermuda grass	1	430	30
Broiler	South	Cullman	AL	01043	Bermuda grass	1	430	30
Broiler	South	Franklin	GA	13119	Bermuda grass	1	430	30
Broiler	South	Scott	MS	28123	Bermuda grass	1	430	30

Table 22. Typical Crop Rotations and Annual Nutrient Removal Rates for Dairy Operations

Sector	Region	County	State	FIPS	Crops	Years in Rotation	N (lb/ac)	P (lb/ac)
Dairy	Central	Erath	TX	48143	Alfalfa/silage	2	239	26
Dairy	Central	Gooding	ID	16047	Alfalfa/silage	5	250	21
Dairy	Mid Atlantic	Lancaster	PA	42071	Alfalfa/silage	3	245	23
Dairy	Mid Atlantic	Wyoming	NY	36121	Silage/wheat	1	292	50
Dairy	Midwest	Marathon	WI	55073	Alfalfa/silage	3	245	23
Dairy	Midwest	Sanilac	MI	26151	Alfalfa/silage	3	245	23
Dairy	Midwest	Stearns	MN	27145	Silage	1	220	35
Dairy	Midwest	Wayne	OH	39169	Orchard	1	252	24
Dairy	Pacific	Tulare	CA	06107	Alfalfa/silage/oats	2	275	31
Dairy	South	Macon	GA	13193	Silage/sorghum/rye	1	490	74

Table 23. Typical Crop Rotations and Annual Nutrient Removal Rates for Swine Operations.

Sector	Region	County	State	FIPS	Crops	Years in Rotation	N (lb/ac)	P (lb/ac)
Swine	Central	Texas	OK	40139	Corn	1	155	19
Swine	Mid Atlantic	Duplin	NC	37061	Soybean/corn/rye	2	196	18
Swine	Mid Atlantic	Duplin	NC	37061	Bermuda grass	1	430	30
Swine	Midwest	Carroll	IN	18015	Corn/soybeans	2	171	16
Swine	Midwest	Cuming	NE	31039	Corn/soybeans	2	171	16
Swine	Midwest	Henry	IL	17073	Corn/soybeans	2	171	16
Swine	Midwest	Martin	MN	27091	Corn/soybeans	2	171	16
Swine	Midwest	Sioux	IA	19167	Corn/soybeans	2	171	16
Swine	Midwest	Vernon	MO	29217	Bermuda grass	1	430	30
Swine	Pacific	Tulare	CA	06107	Alfalfa/silage/oats	2	275	31
Swine	South	Sevier	AR	05133	Bermuda grass	1	430	30

Table 24. Typical Crop Rotations and Annual Nutrient Removal Rates for Layer Operations

Sector	Region	County	State	FIPS	Crops	Years in Rotation	N (lb/ac)	P (lb/ac)
Layers	Central	Gonzales	TX	48177	Bermuda grass	1	430	30
Layers	Mid Atlantic	Lancaster	PA	42071	Corn/wheat/ soybean	2	207	24
Layers	Mid Atlantic	Nash	NC	37127	Soybean/corn/ rye	2	196	18
Layers	Midwest	Clay	IA	19041	Corn/soybeans	2	171	16
Layers	Midwest	Lagrange	IN	18087	Corn/soybeans	2	171	16
Layers	Midwest	Mercer	OH	39107	Corn/soybeans	2	171	16
Layers	Pacific	Riverside	CA	06065	Alfalfa/silage/ oats	2	275	31
Layers	South	Cullman	AL	01043	Bermuda grass	1	430	30
Layers	South	Jackson	GA	13157	Bermuda grass	1	430	30
Layers	South	Washington	AR	05143	Bermuda grass	1	430	30
Layers (wet)	Central	Gonzales	TX	48177	Bermuda grass	1	430	30
Layers (wet)	Mid Atlantic	Lancaster	PA	42071	Corn/wheat/ soybean	2	207	24
Layers (wet)	Midwest	Clay	IA	19041	Corn/soybeans	2	171	16
Layers (wet)	Pacific	Riverside	CA	06065	Alfalfa/silage/ oats	2	275	31
Layers (wet)	South	Cullman	AL	01043	Bermuda grass	1	430	30

Table 25. Typical Crop Rotations and Annual Nutrient Removal Rates for Turkey Operations

Sector	Region	County	State	FIPS	Crops	Years in Rotation	N (lb/ac)	P (lb/ac)
Turkey	Central	Gonzales	TX	48177	Bermuda grass	1	430	30
Turkey	Mid Atlantic	Adams	PA	42001	Bermuda grass	1	430	30
Turkey	Mid Atlantic	Duplin	NC	37061	Soybean/corn/rye	2	196	18
Turkey	Mid Atlantic	Rockingham	VA	51165	Bermuda grass	1	430	30
Turkey	Midwest	Dubois	IN	18037	Corn	1	155	19
Turkey	Midwest	Kandiyohi	MN	27067	Corn/soybeans	2	171	16
Turkey	Midwest	Morgan	MO	29141	Bermuda grass	1	430	30
Turkey	Pacific	Fresno	CA	06019	Alfalfa/silage/oats	2	275	31
Turkey	South	Franklin	AR	05047	Bermuda grass	1	430	30
Turkey	South	Kershaw	SC	45055	Bermuda grass	1	430	30

Table 26. Typical Crop Rotations and Annual Nutrient Removal Rates for Veal and Heifer Operations

Sector	Region	County	State	FIPS	Crops	Years in Rotation	N (lb/ac)	P (lb/ac)
Veal	Central	Erath	TX	48143	Alfalfa/silage	2	239	26
Veal	Mid Atlantic	Wyoming	NY	36121	Silage/wheat	1	292	50
Veal	Midwest	Marathon	WI	55073	Alfalfa/silage	3	245	23
Veal	Pacific	Tulare	CA	06107	Alfalfa/silage/oats	2	275	31
Veal	South	Macon	GA	13193	Silage/sorghum/rye	1	490	74
Heifer	Central	Deaf Smith	TX	48117	Silage/wheat	1	292	50
Heifer	Mid Atlantic	Lancaster	PA	42071	Alfalfa/silage	3	245	23
Heifer	Midwest	Scott	KS	20171	Alfalfa/silage	5	250	21
Heifer	Pacific	Imperial	CA	06025	Alfalfa/silage/oats	2	275	31
Heifer	South	Marion	AR	05089	Bermuda grass	1	430	30

Typical nutrient requirements listed in Tables 20 through 26 were used to set regional application requirements. EPA then used the regional nutrient requirement values in its evaluation of baseline conditions and those expected with potential revised regulations. Fertilization in excess of crop requirements, whether from manure or synthetic fertilizers, means that nutrients are available to wash off of farm fields into the nations waters.

The three manure application rates for baseline conditions simulated with Sample Farm models were as follows:

- All manure applied to available land (up to five times the agronomic N rate).
- N-based, applied at the agronomic N (agronomic N rate includes the actual crop requirements for N plus 30 percent additional manure N to account for typical volatilization and leaching losses).
- P-based, applied at the crop requirements for P.

Additional national assessments were performed with the suite of Sample Farms to assess postrevision conditions. These included an investigation of the impacts of various technology options. For swine operations with lagoon covers or digesters, EPA assumed an increase in the N content of stored manure by 340 percent. For beef and dairy operations that composted their manure, the N in manure was assumed to be more readily available for uptake. This resulted in a 30 percent decrease in application compared to manure that was not composted. Higher N concentrations and availability affect the application rates necessary to meet the agronomic needs, in effect creating additional N- and P-based conditions.

F. Manure Land Application Methods

Cultural practices, such as the method of applying manure, were investigated because they may have a profound impact on the movement of pollutants across fields. EPA evaluated two methods of land application for each manure application rate (discussed below) and spread on the soil surface or incorporated 15 centimeters deep in the soil. Table 27 presents the percentages of those facilities that incorporate manure.

Table 27. Percentages of Operations by Sector that Incorporate Manure.

Sector	Percent of Facilities That Incorporate Their Manure	Source
Beef	30	ERG (2002)
Broiler	15	USDA APHIS (2000)
Dairy	30	ERG (2002)
Layer	15	USDA APHIS (2000)
Swine	30 (<1000 AU) 20 (>1000 AU)	USDA APHIS (2002)
Turkey	15	USDA APHIS (2000)
Veal	30	ERG (2002)
Heifer	30	ERG (2002)

EPA believes there are probably regional variations in land application methods employed for agricultural land areas potentially affected by any rule revision. In its assessment, however, EPA elected to use a constant set of application rates for baseline regulatory conditions and any assessment of potential revisions. By keeping application percentages constant at values shown in Table 27, EPA is assuming that potential rule revisions will not cause a change in the current preferences for one or another land application method. Employing a constant set of values also effectively prevents uncertainty related to application method preference from influencing the outcome of EPA's assessment.

For row crops, EPA assumed that manure application occurred prior to planting. It was assumed that leguminous row crops (e.g., soybeans) under the N-based application scheme had manure N applied at nutrient removal rates. Under the P-based application scheme, legumes had no additional N applied. Forage crops like alfalfa and bermuda grass are perennials that continue to grow each year. Frequent cuttings were required, and the number of cuttings was determined by adding 42 days (the number of days between cuttings, suggested in the GLEAMS documentation) to the planting date until the time when little growth occurs (generally sometime before winter). As many as six cuttings were estimated per year.

Commercial fertilizer additions made up an integral part of the loadings analysis. Commercial fertilizer was applied to the land to equalize the number of acres compared or to supplement the nitrogen demand when applying manure on a P-basis.. The following describes the procedure used to calculate the acreage for manure and commercial fertilizer for a Large 1 broiler operation in the Midwest. Manure nitrogen and phosphorus production and the acreage of facilities with insufficient land to apply manure (Category 2 type facilities) were calculated based on the methodology described in EPA's Cost Model. Adjusted plant nutrient removal was described in the previous section of this report.

For a Category 1 facility, the manured acreage was calculated by dividing the total nutrient produced at the facility by the adjusted nutrient removal rate. For nitrogen, the facility produces 90,833 pounds of N with an adjusted crop removal rate of 171 pounds of N per acre. The number of acres needed to apply all the nitrogen is 531 acres. Similarly, the facility produces 22,375 pounds of phosphorus, has an adjusted crop removal rate of 16.1 pounds of P per acre, and requires 1,387 acres to apply all the phosphorus. The difference between the acres required to apply P and the acres required to apply N for Category 1 facilities is 857 acres, which was assumed to have commercial fertilizer applied at the crop removal rates for both N and P.

A caveat associated with P-based manure application is that there is always a nitrogen deficit. On the 1,387 acres of cropland with manure applied on a P-basis, a total of 90,833 pounds of N was applied, amounting to 65 pounds of N per acre. P-based manure application leaves an adjusted N removal rate balance of 106 pounds per acre. The remaining N needs are met by applying supplemental commercial fertilizer. Because the commercial fertilizer application rate does not need to be adjusted for availability (100 percent available), only 70 percent of the adjusted N removal rate should be supplemented with commercial N fertilizer. Thus, only 74 pounds of N per acre was applied to the 1,387, acres for a total of 102,638 pounds of N added to supplement manure applied for this category 1 operation on a P-basis.

For Category 2 facilities, the number of acres for onsite manure application was already known based on an analysis of the 1997 Census of Agriculture by USDA described in EPA's Cost Model Report. For Large 1 N-based broiler facilities in the Mid Atlantic Region, the acreage of farms without enough land to apply manure was 233 acres; for facilities without enough land to apply phosphorus the acreage was 453 acres. These acreage values reflect manure that is applied onsite. To equalize these acreage values, the difference was calculated (220 acres) on which commercial fertilizer was applied for N-based conditions.

The first step in calculating the offsite acreage for Category 2 facilities is to determine whether the onsite manure application rate is greater than five times the agronomic N rate (the application cap was exceeded only 34 times in this analysis). The assumption is that if a facility contains more than five times the adjusted nitrogen removal rate, then the facility transports this manure to offsite land under baseline conditions. For this example, the total N produced divided by the category 2 N acreage is less than 5. Thus, for the baseline condition, there is no manure applied offsite for category 2 facilities. EPA assumed that all offsite manure is applied on a nitrogen basis. Thus, any manure thatdoes not fit onto the cropland is applied to offsite acreage on a nitrogen basis. Category 3 facilities have no land, and all manure is applied offsite. Table 28 presents the acreage associated with the various application schemes cited in our example.

Table 28. Manured, Commercially Fertilized, and Total Acreage for Baseline, N-Based, and P-Based Conditions for the Various Categories, Onsite and Offsite Situations

	Baseline			N-Based Application			P-Based Application		
Application	**Manure**	**Com.**	**Total**	**Manure**	**Com.**	**Total**	**Manure**	**Com.**	**Total**
Category 1	531	856	1,387	531	856	1,387	1,387	0	1,387
Category 2 Onsite	233	221	454	233	221	454	454	0	454
Category 2 Offsite	0	714	714	596	118	714	714	0	714
Category 3	531	0	531	531	0	531	531	0	531

G. Production Area Loads

Loads that occur from the production area have three components. The first production area load component occurs from stacked manure and is important for dry poultry (broilers, layers, and turkeys). These loads are proportional to the size of the stacked manure pile and the amount of rain falling on the pile. The other two components occur from liquid storage systems. The liquid storage system production area loads have either an overflow fraction or a groundwater fraction. For EPA's analysis, feedlot runoff loadings combined with loadings from manure storage structure (e.g., lagoon) leakage and the land application of manure to equal the total nutrient load per Sample Farm (or facility). The amount of contaminant in feedlot runoff depends on the rainfall amount and varies by AFO region and the sector.

For baseline within the GLEAMS model, EPA assumed that its rule revision will not affect feedlot runoff management at large-sized facilities in any of the sectors, except for dry poultry operations. Existing NPDES permit requirements currently regulate large AFO discharges, requirements that are not affected by the proposed rule revisions. However, production area loads at medium-sized AFO facilities are affected by EPA's suite of potential rule revisions.

To estimate the AFO loadings conveyed by runoff for stacked poultry manure, EPA assumed that runoff from the pile contains 1.5 percent solids (Midwest Plan Service: Livestock Waste Facilities Handbook). Thus, the depth of rainfall (in feet) multiplied by the square footage of the pile provides the total amount of runoff from the stacked manure. EPA estimated pollutant loadings for other pollutants based on the relative concentration within wet manure; the runoff load for pollutant "X" was estimated by multiplying the estimated phosphorus load by the ratio of pollutant "X" found in Table 3. EPA assumed that any facility had a pile of stacked poultry manure exposed to rainfall 25 percent of the year. Each feedlot loadings estimate was converted into a dry basis for addition to other dry-basis loadings from edge-of-field Sample Farm models.

Liquid manure storage structures are potentially large sources of pollutant loadings arising from seepage to groundwater or surface discharge due to overflow. Overflows occur at lagoons under a number of conditions, but the most common is when high levels of rainfall overwhelm the available storage within a lagoon. As detailed in a memorandum found in Appendix B for beef and dairy and in Appendix C for swine and wet layers, EPA's methodology estimated the potential overflows and corresponding pollutant loads from liquid containment structures that occur over a 25-year period. EPA estimated overflows for the production area due to the daily inputs to the storage system, including process wastes, direct precipitation, and runoff. EPA also evaluated the daily outputs from these storage systems, including losses due to evaporation, sludge removal, and the removal of wastewater for use on cropland onsite or offsite. For purposes of this analysis, EPA defined the annual overflow as the median annual overflow over the 25 years evaluated. EPA coupled animal-specific pollutant characterization data with the overflow volume output from the model to predict the mass pollutant discharge for each facility. Finally, EPA used weighted facility counts to estimate the total industry pollutant loadings for beef feedlots, heifer operations, and dairies for both baseline systems and the regulatory options.

Comprehensive studies conducted in North Carolina (Sheffield, 2002) and Iowa (Iowa State University, 1999) conclude that all such liquid impoundments leak, although the rate of leakage varies by soil type and liner construction (if any). Most studies of the lagoon leakage estimated groundwater loads by simulating transport of pollutants through groundwater aquifers. For example, seepage estimates were obtained from Ham and DeSutter (1999), who measured nitrogen that leaked from three established swine-waste lagoons in Kansas. In this study, lagoon walls and bottoms had either an indigenous silt loam soil that was compacted to a thickness of 12 to 18 inches or an 18-inch-thick clay liner. Their results showed that lagoon ammonium-N export loads ranged from 1,952 pounds per acre per year to 2,434 pounds per acre per year.

For its Sample Farm model, EPA assumed that 2,000 pounds per acre per year leaked from manure storage structures lined with silt loam soils. This reference value was used to develop direct and indirect manure storage structure leakage loadings according for other soil types (i.e., soil permeability) based on work by Clapp and Hornberger (1978). The Clapp and Hornberger soil permeability rates were matched with each soil type modeled. Clapp and Hornberger (1978) reported soil permeabilities ranging 2 orders of magnitude over all soil types. For example, they reported that water flowed through sand about 100 times faster than clayey soils and about 10 times faster than silty soils. Using this analogy of flow rates for various textures, EPA scaled the silt loam ammonium export from Ham and DeSutter (1999) to reflect changes in soil texture for Sample Farms. Thus, for silt loam soils, it was assumed that 2,000 pounds of nitrogen per acre per year would seep out of manure storage structures; for sandy soils, 20,000 pounds of nitrogen per acre per year; and for clay soils, only 200 pounds of nitrogen per acre per year.

The leakage values reported by Ham and DeSutter (1999) are for ammonium, which is not mobile in soils. For ammonium to mobilize, oxygen must be present to oxidize the ammonium to nitrate. Once nitrate is formed, it can leach to groundwater. Because soil under lagoons generally remains wet and anaerobic, only the outer fringe of the lagoon may oxidize and leach. EPA assumed that 10 percent of the ammonia-nitrogen is oxidized to nitrate and reaches groundwater.

Sobecki and Clipper (1999) determined how many manure storage structures had direct seepage losses by evaluating the groundwater pollution potential of AFO manure storage structures according to AFO region land characteristics. For these structures with a direct surface link, pollutant loads were assumed to directly connect with surface water and it was assumed that no groundwater aquifer pollutant assimilation took place.

Consequently, for manure storage structures that had a high groundwater pollution potential under Sobecki and Clipper (1999) analysis, once lagoon leakage took place there were no pollutant reductions before this pollutant load hit surface water. Sobecki and Clipper assumed that if regional characteristics indicated there was a relatively high groundwater pollution potential, these manure storage structures would leak. Some of the criteria they used to make groundwater pollution potential determinations were sandy soils through the soil profile, the presence of a shallow groundwater table, and the presence of karst or karst-like terrain. These groundwater pollution potential criteria were evaluated, and percentages of land area were developed for each AFO region. The percentages in Table 29 were applied to each Sample Farm in an AFO region, and these percentages defined baseline levels for manure storage structure leakage to ground water sources.

Table 29. Acreage with Potential for Groundwater Contamination

CAFO Region	Percentage	100-Percentage
Mid Atlantic	23.91	76.09
South	22.45	77.55
Midwest	27.46	72.54
Central	12.60	87.40
Pacific	12.28	87.72
Total (U.S.)	22.86	77.14

Source: Sobecki and Clipper, 1999

IV. Model Sensitivity and Comparison with Results in Literature

As a part of its rule-revision evaluation, EPA sought to compare edge-of-field Sample Farm model results with published and reported pollutant loadings estimates available within the literature. Through comparing modeled and reported results, EPA attempted to validate the model results and establish that the model predicts reasonable results. In addition, EPA performed limited sensitivity assessment of key model parameters to assess how parameter variation would affect model results. EPA also assessed the variability of model predictions that are attributable to climatic and soil variability. Again, EPA's goal was to verify the reasonableness of its analysis of the industry.

A. Comparison of Sediment and Nutrient Loading Simulations to Measured Data

To evaluate simulated estimates of pollutant loadings, measured data from a variety of sources were compared to the simulated values. The vast majority of measured field discharges and loads are for fields managed with synthetic fertilizers. As a result, EPA's review of GLEAMS modeling focused on edge-of-field comparisons based on simulated synthetic fertilization where surface application is used. If Sample Farm simulations based on synthetic fertilizers falls within measured ranges, then EPA believes its simulation of manure-based fertilization is also reasonable. EPA's comparison of simulated and measured values focused on per acre average annual loadings for a 25 year period. Table 30 compares simulated sediment losses with referenced measured values in the AFO regions.

Overall, EPA's regional average annual loadings compares relatively well with literature values. As shown in Table 30, the average simulated sediment load generally falls in the lower half of the published range. Maximum and minimum simulated averages for the 25-year period generally cover a wider range than found in literature, but have the same magnitude of variation. The exception of this is the Mid-Atlantic, where a relatively small sample set of *measured values* were reviewed. Because EPA evaluated a extensive range of soils, operating under diverse hydrologic conditions (48 rain gauges and over 60 different soil types), it is reasonable to expect the simulated maximum and minimum values will span a range greater than that reported in literature. For its national assessment, EPA believes it is sufficient to have the bulk of the simulated values fall within the range in the literature, allowing for some values to exist outside of published ranges. In terms of manure, EPA's simulation of *manure-based* fertilization produces about the same overall average and range in annual average sediment discharge as shown in Table 30 for synthetic fertilization.

Table 30. Simulation and Measured Sediment Losses in the AFO Regions

AFO Region	Simulated Minimum, Average, and Maximum Sediment Loss	Measured Sediment Loss
	pounds per acre per year	
Pacific	95, 155, and 210	< 4,000[a]
Central	470, 1212, and 2644	18 – 6,030[a]
Mid Atlantic	347, 3810, and 22190	200 – 500[b]
Southern	45, 4990, and 48370	
Midwest	34, 2165, and 13500	560 – 11,200[c]

[a] Brady, 1992.
[b] Maryland Department of Agriculture, personal communication, May 1999.
[c] Ginting et al., 1998.

The simulated and measured surface nitrogen and phosphorus losses based on synthetic fertilization are shown in Table 31. Note, the values shown are a combination of soluble and sediment bound fractions averaged over the 25 year simulation period. In general, the simulated regional average value and the range compares relatively well with measured nutrient values. Differences in annual nutrient discharge are expected due in part to diversity of soils, crop selection, and climatic variation. Regional measured values represent ranges found from a variety of agricultural land uses, for example those from Novotny and Chesters (1981). Surface nutrient discharges can vary by more than one order of magnitude, as found by Chesters et al. (1978) who reported 4.8 to 35 pounds N per acre and 0.2 to 4.5 pounds P per acre under agricultural systems.

The comparison of simulated and measured loads (based on the use of synthetic fertilizer), demonstrates relatively close agreement. For some regions, EPA's nutrient discharges tend to be higher than those measured, for other regions it tends to be lower. In the absence of an in depth review of specific conditions (a single soil type located in a single region that experiences a specific crop under an established rotation cycle) it is not possible to perform a detailed comparison of measure and simulated values. However, EPA believes the level of accuracy obtained for nutrients is sufficient to permit its national assessment of plausible revisions of effluent guidelines.

Table 31. Nitrogen and Phosphorus Surface Loading Results from GLEAMS for Pre-Regulation Sample Farms and Comparisons to Literature Values

AFO Region	Simulated Minimum, Average, and Maximum (Baseline with N-Based Application Rates)		Measured	
	Surface N	Surface P	Surface N	Surface P
	pounds per acre			
Central	4, 9, 17	7, 10, 21	2-20[d]	1.4-10.6[d]
Southern	1, 14, 47	1, 13, 44	2-8[a]	1-3[a]
Mid Atlantic	3, 7, 17	3, 10, 19	13-19[b]	9-15[b]
Pacific	1, 2, 3	3, 4, 5		
Midwest	1, 6, 17	1, 6, 16	3-54[c]	2-42[c]

[a] Edwards et al., 1993
[b] Quisenberry et al., 1980.
[c] Ellis et al., 1978.
[d] Saunders and Maidment, 1996.

Because its simulation of synthetic fertilizer with the Sample Farm models is reasonable, EPA believes its simulation of manure-based fertilization will also be reasonable. The basic difference between synthetic and manure based fertilization is inherent to the nutrient content of manure. Manure applied to meet N-based requirements will inherently provide excess agronomic levels of P, whereas manure applied to meet P-based requirements will inherently be deficient of N (not including supplemental synthetic nitrogen).

B. Comparison of Pathogen Loading Simulations to Measured Data

Few literature references are available on simulated and observed pathogen. EPA has developed Total Maximum Daily Loads for pathogens for various waterbodies throughout the country. This work has not focused on the transport dynamics of pathogens but rather has used associated percentages to estimate pathogen loadings. However, a few studies were found that measured the fecal coliform and fecal streptococcus concentrations in runoff. One study was conducted in northwest Arkansas, where Edwards et al. (1993) measured the fecal coliform and fecal streptococcus concentrations from fields where poultry litter was land applied. This reference was used to develop pathogen concentrations, decay rate, and adsorption coefficient input parameters for the GLEAMS model (Knisel et al., 1993). These parameters were then used to conduct pathogen simulations. GLEAMS simulation results (for rainfall-runoff events) with these input parameters were well within the range of values measured by Edwards et al. (1993).

C. Comparison of Metal Loading Simulations to Measured Data

Metal loading to surface waters occurs naturally even without the addition of manure because metals are already present in the soil. In addition, atmospheric sources ensure that trace levels of metals are present in both rural and urban settings. However, the application of manure on the soil surface increases the potential for metals to reach surface waters because the manure contains metals.

Few sources are available that describe the edge-of-field metal loads from manure application. Much of the work of monitoring metal concentrations in runoff has been conducted in an urban setting. Results from Marsalek (1978) for heavy metal runoff from urban land are presented in Table 32 along with average metal loads from model simulations.

Table 32 demonstrates the influence of fertilizer type and application rate on annual metal loadings. First, synthetic fertilizer contains lower metals concentrations than manure and produces much lower metals loading rates. On a per acre basis, AFO cropland with synthetic fertilization produced significantly lower metals loadings than those measured for urban settings. Nickel produces the closest comparison, however synthetic fertilized AFO acreage produce an estimated 6% of urban loadings determined by Marsalek (1978). Overall, EPA believes it is reasonable for its Sample Farm models to predict synthetic fertilizer loadings well below urban values.

Table 32 indicates manure fertilized AFO cropland has much higher metal loadings. In the case of baseline conditions (manure applied in excess of agronomic levels), EPA's Sample Farm models indicate that metal loadings can match and exceed urban levels from Marsalek. Even where manure is agronomically applied, the higher initial metal concentrations in manure produce significantly higher loadings than synthetically fertilized cropland. Overall, application at agronomic N levels reduces metals loadings on the order of 30 to 50% of current (baseline manure) levels.

Based on the relative nature of simulated metal loading values, EPA believes the Sample Farm model results are reasonable for assessing potential benefits. A higher level of verification is possible, namely a comparison on the basis of measured and modeled loadings for specific watersheds. While this would be of value, it is beyond the scope of EPA's national assessment to perform this type of assessment. The diversity of watersheds, variation in soil and water chemistry, and time/fiscal limits on EPA prevent a detailed confirmation of simulated results shown in Table 32.

Table 32. Typical Urban and Sample Farm Simulated Metal Loading Rates (Simple average across all Sample Farm Model results)

Metal	Marsalek	Synthetic (a)	Typical Current Manure Fertilization (b)	Manure Agronomic N-based (c)
	Average annual, pounds per acre	Simulated 25 year average discharge in pounds per acre per year		
Zinc	1.2190	0.00090	1.7100	1.2100
Copper	0.1220	0.00160	0.3800	0.2100
Cadmium	0.0300	0.00002	0.0060	0.0052
Nickel	0.0640	0.00400	0.1030	0.0486
Lead	0.3100	0.00340	0.0610	0.0602

[a] Based on synthetic fertilization of fields at agronomic rates using surface application.
[b] Fertilization with manure using surface application at baseline rates.
[c] Agronomic fertilization using surface application for typical local crops with manure for N.

D. Sample Farm Model Sensitive Assessments

1. Sensitivity to Climate Representation

EPA performed a sensitivity analysis of the meteorologic gauges selected by EPA, gauges that serve as the basis for estimating potential national pollutant loadings reductions. EPA used the simulated individual farm performance within the top production counties (generally located in each of the 10 top producing states) to estimate total regional performance. The Sample Farm process used by EPA sought to account for climate variation on a state-to-state basis and within a CAFO region (see Figure 7).

To demonstrate the acceptability of its approach, EPA performed state-by-state and regional comparisons to assess the representativeness of the meteorologic gauges it used. To support the Sample Farm models, EPA selected 48 gauges from the approximately 1,000 gauges available in the CLIGEN database (Nicks, 1985), a meteorologic database that spans the contiguous states. To assess gauge representativeness, EPA first assumed the 1,000 CLIGEN gauges collectively describe the climate within the contiguous states. This provided a basis for reporting on the representativeness of the 48 select gauges against the larger population of gauges for the top production states.

EPA focused its meteorologic gauge evaluation on the top-producing states; the 26 states represented within the 13,500 Sample Farm models make up between 64 and 87 percent of the total national production. Hence, EPA based its gauge review on the ability of the 48 select gauges to represent the total pool of gauges within the 26 key states. In addition, EPA summed up the per state comparison to evaluate total regional and national performance. EPA based its gauge comparison on arithmetic annual averages and range encompassed within +/- one standard deviation from the average based on 50 years of statistically generated daily precipitation records. Wherever multiple gauges were found within a single state, EPA used the simple arithmetic average of the gauges to estimate collective state performance (i.e., there was no weighting of gauges based on per county production rates or spatial coverage). As a general rule, EPA selected its gauges because they were the closest to the top-producing counties within the top-producing states, an operation performed on a sector-by-sector basis.

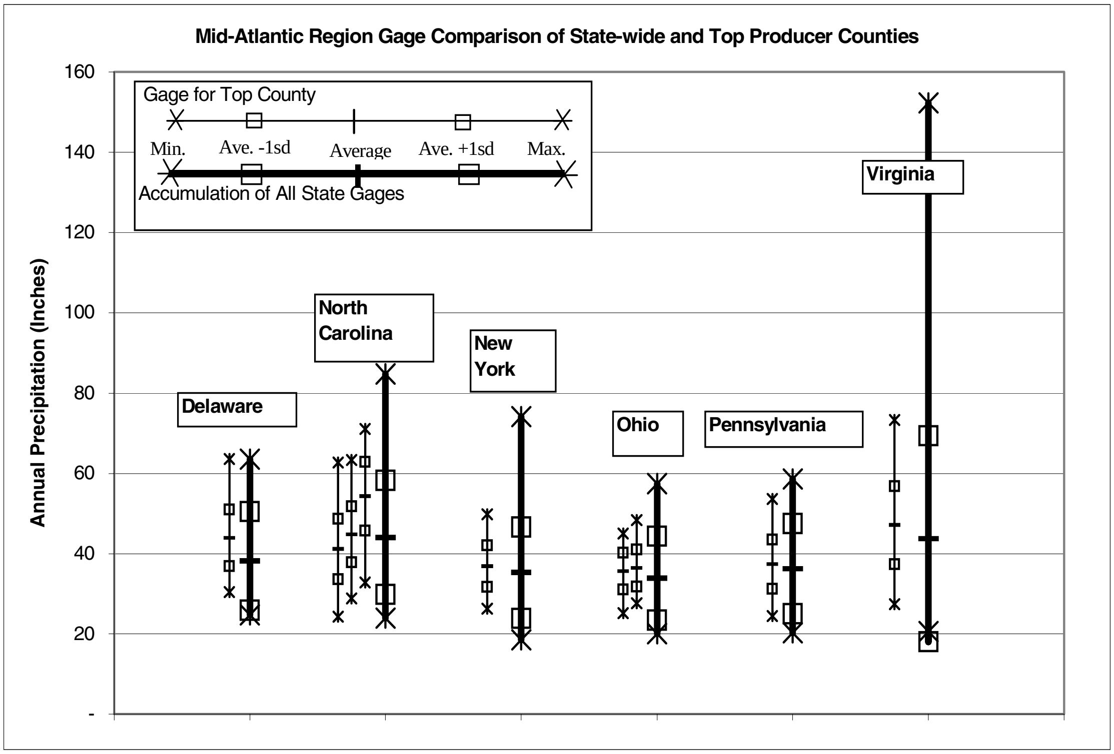
The results of EPA's per state and per regional review of the 48 gauges against the total greater pool of gauge data are shown in Table 33. In summary, Table 33 indicates the overall high representativeness of the 48 gauges. For most states, the per state averages resulting from the 48 gauges depart from those resulting from the 1,000 CLIGEN gauges by less than 20 percent. For 15 states, selected gauges predict average values above the all-gauge pool, and for 11 states the select gauges predict lower averages. In addition, the largest departures (e.g., California and Idaho) are underpredictions (i.e., selected gauges indicate less precipitation than the collective average of all gauges within the state). Note that underpredicting total precipitation is conservative (disfavors regulation) because less rainfall correlates with less pollutant runoff. In summary, both regional averages and national averages indicate that the 48 gauges depart only slightly from all-gauge results. The one exception is the Pacific CAFO region, where EPA's use of select gauges probably results in an underprediction of the state and regional average pollutant loadings.

For each of the five CAFO regions, Figures 9 through 11 compare select gauge and all-gauge performance on a state-by-state basis. For each gauge illustrated on each figure, the range of annual precipitation values is shown, along with the simple average annual value. In addition, the annual precipitation values associated with a +/- one standard deviation departure from the arithmetic average are shown. Collectively, the five graphed precipitation values within the figures provide significant information on the nature of THE precipitation over a 50-year period.

Table 33. Average Annual Precipitation for Top Producing CAFO States

State	CAFO Region	Average of All Gauge Values within State	Average of Select Gauge Values	Per State Average Departure
CO	Central	12.88	13.78	-7
ID	Central	18.22	12.61	31
OK	Central	31.02	32.12	-4
TX	Central	25.61	29.86	-17
Central Region Average		21.93	22.09	1
DE	Mid Atlantic	40.51	43.89	-8
NC	Mid Atlantic	46.74	46.73	0
NY	Mid Atlantic	37.47	36.88	2
OH	Mid Atlantic	36.04	36.00	0
PA	Mid Atlantic	38.55	37.33	3
VA	Mid Atlantic	46.41	47.09	-1
Mid Atlantic Region Average		40.95	41.32	-1
IA	Midwest	30.53	26.22	14
IL	Midwest	36.74	37.01	-1
IN	Midwest	37.98	38.53	-1
KS	Midwest	26.51	19.79	25
MI	Midwest	30.44	25.10	18
MN	Midwest	24.68	27.50	-11
MO	Midwest	37.53	42.07	-12
NE	Midwest	22.57	26.94	-19
WI	Midwest	30.16	30.94	-3
Midwest Region Average		30.79	30.46	1
CA	Pacific	19.48	10.51	46
Pacific Region Average		19.48	10.51	46
AL	South	55.07	59.75	-8
AR	South	47.09	44.00	7
FL	South	51.18	58.09	-13
GA	South	48.90	57.35	-17
MS	South	54.90	55.74	-2
SC	South	46.46	41.86	10
South Region Average		42.82	42.23	8
National Average (The simple average of all state values)				1

Note: Departure is calculated based on the difference in averages divided by the all-gauge average All average values are the arithmetic average based on 50 years of record and the simple average of all gauges on a per state basis.



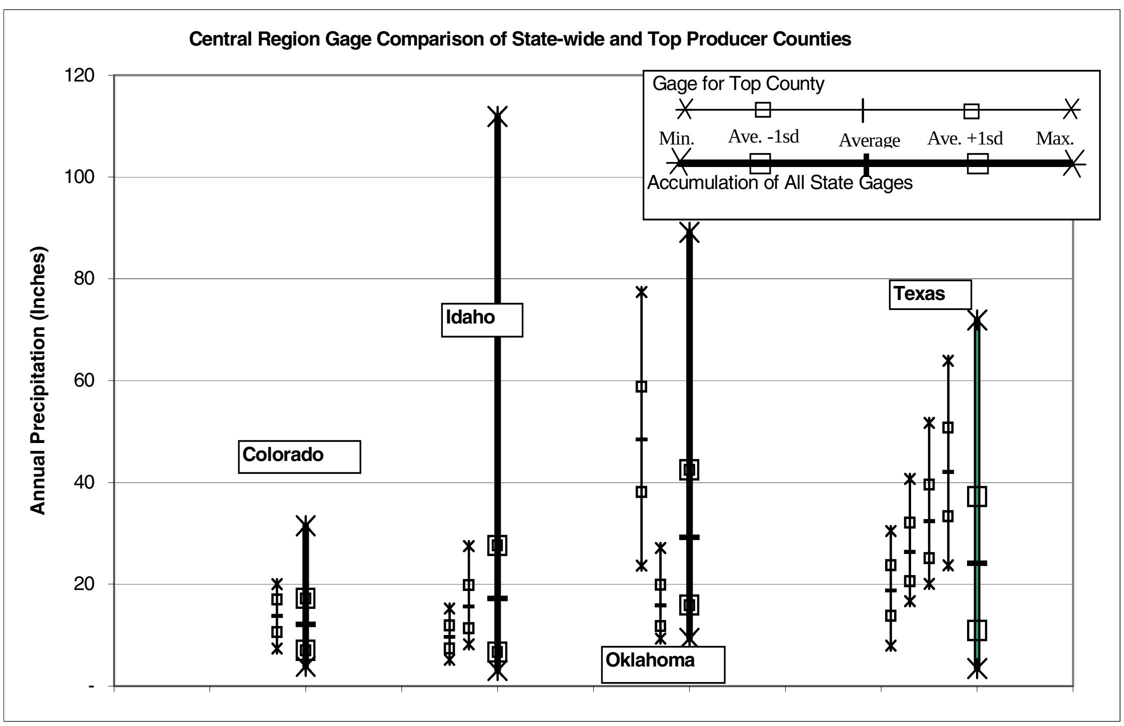
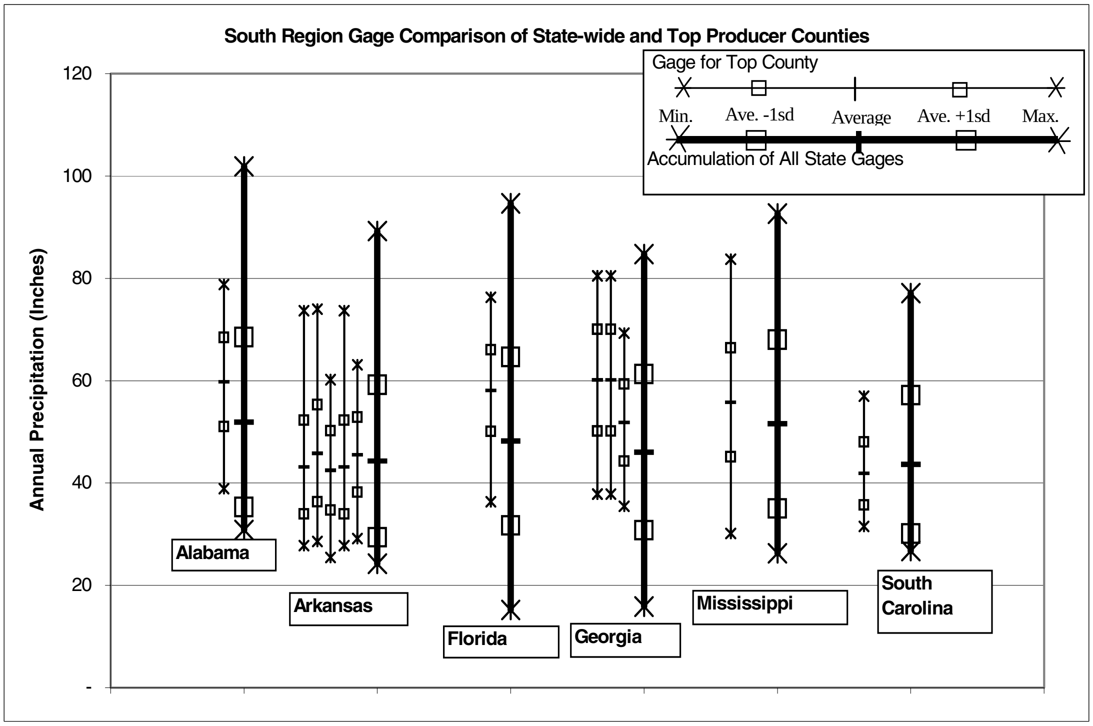


Figure 9. Mid Atlantic and Central CAFO Region precipitation gauge comparison



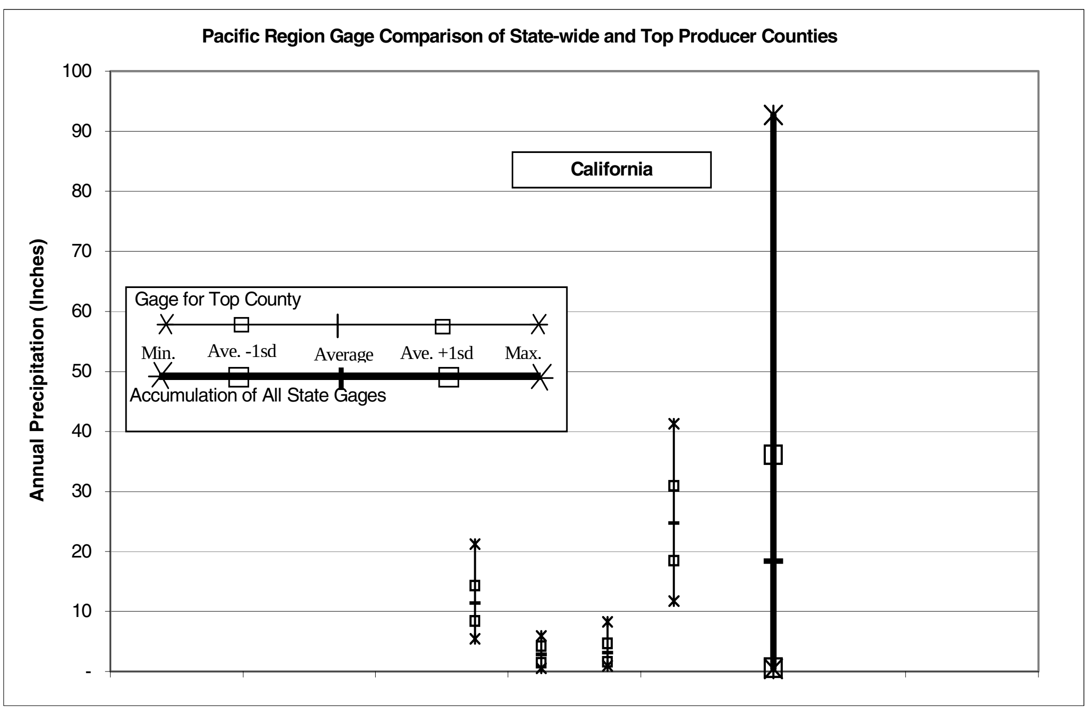


Figure 10. South and Pacific CAFO Region precipitation gauge comparison.

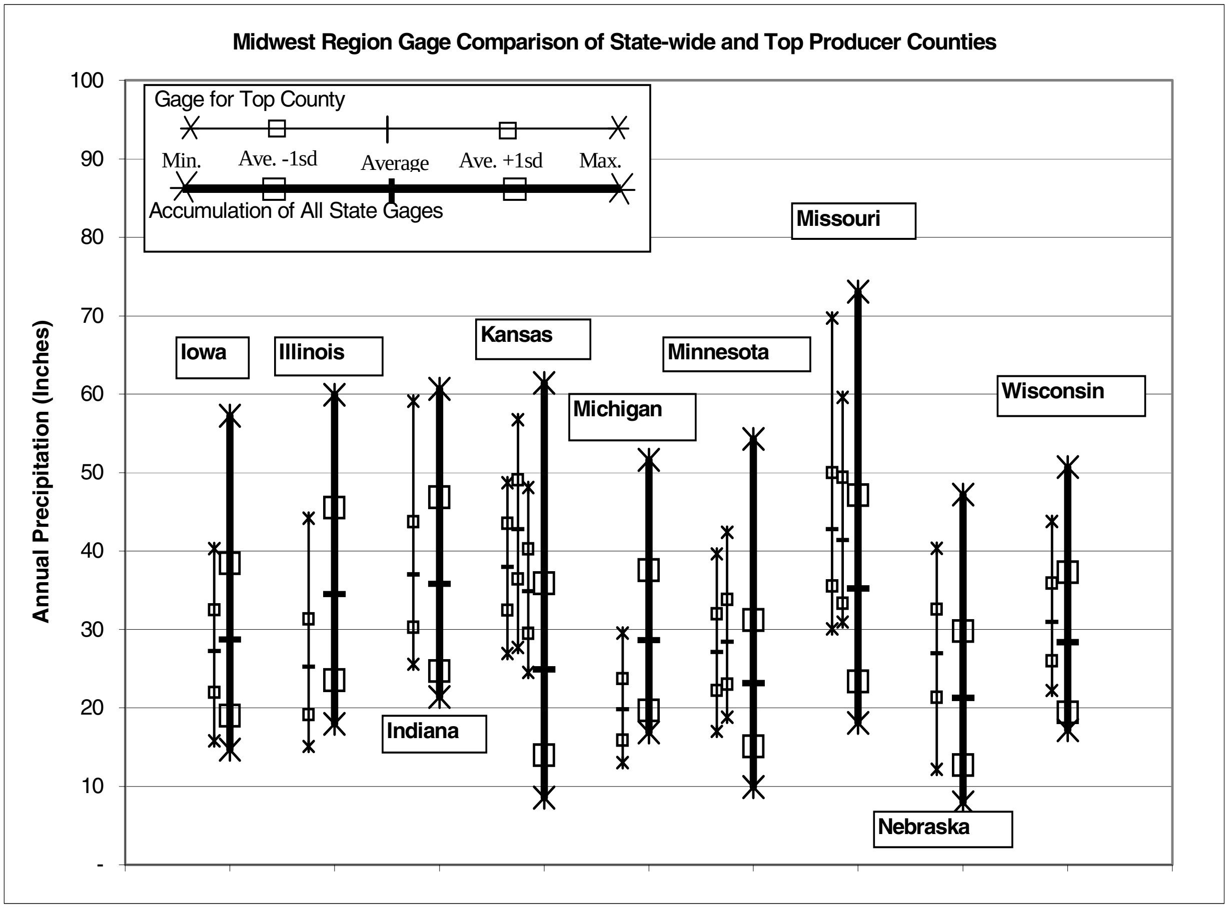


Figure 11. Midwest CAFO Region precipitation gauge comparison

As an example comparison, Figure 9 indicates that EPA selected three gauges to represent farms within North Carolina (covering sector-specific top production counties found in the state). The three select gauge statistics are compared to the state statistics derived from all CLIGEN gauges located within the state. Figure 9 indicates that the EPA select gauge statistics align relatively closely with those of the all-gauge statistics, and that there is a high degree of overlap between the range enclosed between +/- one standard deviation. As expected there are some differences in the maximum and minimum values, because state all-gauge statistics originate from a much greater number of gauges. For North Carolina all-gauge statistics are based on 22 gauges, not 3 gauges, so a much greater range of precipitation is expected and the all-gauge standard deviation is also greater.

The state-by-state review of the gauges selected by EPA suggests the gauges are relatively representative of statewide conditions. So the climate within the top production counties establishes, to a reasonable level, the climate of CAFO facilities within other counties located within each state. It is not feasible for EPA to analyze industry operations using all 1,000 CLIGEN gauges, a step that would increase the number of Sample Farm models by 2,100 percent over the 13,500 models derived from the 48 select gauges. By analyzing per farm performance based on the climate in top production counties, EPA has biased its assessment on locations preferred by the industry.

Figures 9 to 11 illustrate the range in annual precipitation indicated by select gauges. Overall, select gauges indicate an average coefficient of variation of 0.20 percent, which suggests the average annual precipitation describes relatively well the 50 years of annual precipitation values. In addition, the 50 years of records include wet and dry years; on average the maximum and minimum values are 2.5 and 2.0 standard deviations from the simple average. In other words, the maximum and minimum values are 152 and 61 percent of the average annual precipitation value, respectively.

In summary, EPA's characterization of climate produces reasonable representations on the basis of states and CAFO region. Climates within top production counties represent reasonably well the climate within the state. Overall, while top production county climate departs from statewide climate, there was a tendency for over- and underestimations to cancel out on a regionwide basis. Based on the 26 top production states (representing 64 to 87 percent of the industry total production), the simple average of annual precipitation recorded at 48 EPA-selected meteorologic gauges falls within 1 percent of that derived from the total pool of long-term precipitation records in the same states.

2. Sensitivity to Soils Representation

One of the key objectives of EPA's individual assessment of soils of top production counties was to obtain as much representativeness of conditions at CAFO facilities as possible. EPA originally used the single most common agricultural soil within each county to estimate the most probable pollutant generation from CAFO facilities. Based on STASTGO information on the top soil layer, the single most common soil represented between 11 and 54 percent of the agricultural footprint within the top production counties examined, and on average made up 24 percent. In response to comments from EPA's 2001 Notice of Data Availability, there was widespread support from academic professional societies (e.g., American Society of Agronomy, Crop Science Society of America, Soil Science Society of America; CAFO400246-34), state and environmental agencies (e.g., Wisconsin Department of Natural Resources, CAFO400148-12; Wisconsin Department of Agriculture, Trade and Consumer Protection, CAFO400249-16; and Minnesota Department of Agriculture, CAFO400165-38), and industry (e.g., Dairy Producers of New Mexico, CAFO400112-35 and Idaho Dairymen's Association, CAFO400247-39) for EPA increased the number of Sample Farm models 300 percent, performing individual analyses of the three most common agricultural soils found in each county. The composited countywide result was then computed by weighting the individual results of each of the three most common soils (i.e., weighting based on their relative contribution to the collective total agricultural footprint).

The STASTGO information indicates the three most common soils represented between 33 and 93 percent of the btotal agricultural footprint within the top production counties, and on average made up 54 percent. These percentages demonstrate the dominance of the three most common soils within the agricultural footprint and the high degree of representativeness provided by EPA's three-soil approach. Table 34 indicates the relative contribution of the single most common and the three most common soils for top production counties. On average, agricultural land areas within a single county contained 11 different soil series, but may have had as few as 9 or as many as 15 soil series.

Table 34. Geographic Coverage of Common Soils within CAFO Counties

Top Production State	Top Production County	Percentage of the Most Common Soil among All Agriculture Soils	Percentage of the Three Most Common Soils among All Agriculture Soils
Alabama	Cullman	15.5	45.4
Florida	Marion	19.6	47.7
Georgia	Franklin	23.2	48.7
Georgia	Jackson	20.3	51.6
Georgia	Macon	26.0	50.9
Idaho	Cassia	21.3	45.7
Idaho	Gooding	17.7	39.6
Illinois	Henry	16.1	47.4
Indiana	Carroll	22.7	54.2
Indiana	Dubois	18.7	48.5
Indiana	Lagrange	50.5	77.3
Iowa	Clay	28.4	50.8
Iowa	Sioux	38.5	81.9
Kansas	Scott	24.4	59.6
Maryland	Somerset	17.4	42.8
Maryland	Wicomico	18.5	45.4
Maryland	Worcester	17.9	42.4
Michigan	Sanilac	13.3	38.7
Minnesota	Kandiyohi	15.7	40.5
Minnesota	Martin	17.3	42.2
Minnesota	Stearns	11.6	32.5
Mississippi	Scott	35.5	58.2
Missouri	Barry	15.0	43.8
Missouri	Morgan	38.5	81.9

Top Production State	Top Production County	Percentage of the Most Common Soil among All Agriculture Soils	Percentage of the Three Most Common Soils among All Agriculture Soils
Missouri	Vernon	29.6	59.1
Montana	Carter	29.6	59.8
Nebraska	Cuming	21.4	59.2
New Mexico	Chaves	26.8	53.6
New York	Wyoming	19.5	43.3
North Carolina	Duplin	15.1	43.8
North Carolina	Nash	29.1	58.1
North Carolina	Wilkes	23.9	56.8
Ohio	Knox	32.1	64.2
Ohio	Mercer	32.1	64.2
Ohio	Wayne	11.6	32.5
Oklahoma	Texas	19.3	49.4
Pennsylvania	Adams	34.1	55.7
Pennsylvania	Berks	34.1	55.7
Pennsylvania	Bradford	20.5	47.3
Pennsylvania	Franklin	25.3	63.7
Pennsylvania	Lancaster	17.9	49.5
Pennsylvania	Lebanon	34.1	55.7
South Carolina	Kershaw	20.3	51.6
South Dakota	Butte	15.5	42.3
Texas	Crockett	30.1	63.0
Texas	Deaf Smith	54.1	93.5
Texas	Erath	24.7	52.0
Texas	Gonzales	30.1	63.0
Texas	Shelby	26.6	58.6
Utah	Box Elder	25.5	54.0
Arkansas	Benton	30.3	66.6
Arkansas	Franklin	37.0	59.8
Arkansas	Marion	30.3	66.6
Virginia	Accomack	16.7	44.9
Virginia	Page	18.5	45.4
Virginia	Rockingham	23.5	59.2
Arkansas	Sevier	30.1	48.7
Arkansas	Washington	30.3	66.6
Wisconsin	Marathon	13.3	38.7
Wyoming	Johnson	20.3	49.2

Top Production State	Top Production County	Percentage of the Most Common Soil among All Agriculture Soils	Percentage of the Three Most Common Soils among All Agriculture Soils
California	Fresno	21.0	52.4
California	Imperial	14.7	41.9
California	Riverside	16.8	49.3
California	Tulare	13.9	40.9
Colorado	Weld	24.4	59.6
	Maximum	54.1	93.5
	Minimum	11.6	32.5
	Average	24.1	53.2

Note: Percentages indicate the fraction of total agriculture land in the county (i.e., the agricultural footprint) containing the soil series.

By using an independent evaluation of the three most common soils (not only the most common soil), EPA approximately doubled the percentage of agriculture soil simulated within the Sample Farm models. Overall 53 percent of the agriculture soil footprint is represented by an individual Sample Farm model, which serves as the basis for inferring the probable behavior of the 47 percent not directly represented by Sample Farm models.

EPA also made a comparison based on soil textural class, comparing textures for the three most common soils against the suite of textures encountered in all agriculture soils (based on the top soil layer). Collectively the top production counties evaluated by EPA contain a total of 39 different soil textures (e.g., silt, silty loam, silty clay) within the top soil layer. Such a wide variety of possible soil textures makes it difficult to identify a single or a few dominant textures for all agriculture soils in the nation. It also makes it appear unlikely that three soils (perhaps three different soil textures) can reasonably represent the suite of agriculture soils in a single county. However, based on a county-by-county evaluation, the soil textures found in the top three soils match between 42 and 100 percent of all agriculture soils in each top production county, averaging 73 percent. So if the three most common agricultural soils in a single county are loam, loamy silt, and silty loam, the collective agriculture area found in these three soil texture classes would probably be around 73 percent within the county. The commonality between the three most common soils in each county and the total suite of agricultural soils strongly supports EPA's Sample Farm approach.

In summary, EPA's 13,500 Sample Farm models represent 54 percent of the agriculture footprint in the top production counties based on soil series, and 73 percent based on soil texture class. As a result, the suite of Sample Farm models will provide a reasonably high level of representativeness of county-by-county soil conditions at CAFO facilities. EPA's suite of models simulates the behavior of the majority of the agricultural land receiving CAFO manure. This suggests that inferring the probable behavior of the soils not simulated in the Sample Farm models should not impose a large error within EPA's evaluation of potential changes in effluent guidelines.

V. Processing Sample Farm Pollutant Loads to National Total Load Estimates

As demonstrated in Sections II and III, EPA's assessment of edge-of-field or per farm pollutant loadings for a large number of Sample Farms required extensive database development. To orchestrate the feeding of sample model data into GLEAMS, EPA developed a processor (using the FORTRAN programming language), referred to as the Loadings Estimate Tool (LET). This program extracts data from several large databases, forms an input data file suitable for GLEAMS, feeds the data into GLEAMS, and then regulates GLEAMS output. LET also integrates pollutant loadings estimates from open-air feedlots, manure piles, and leaking lagoons, to estimate average annual total pollutant loadings.

Figure 12 presents an overview of the methodology used to estimate the edge-of-field loadings of nutrients, sediments, metals, and pathogens. Sample Farm loads were subsequently extrapolated to the AFO region and to national pollutant loads.

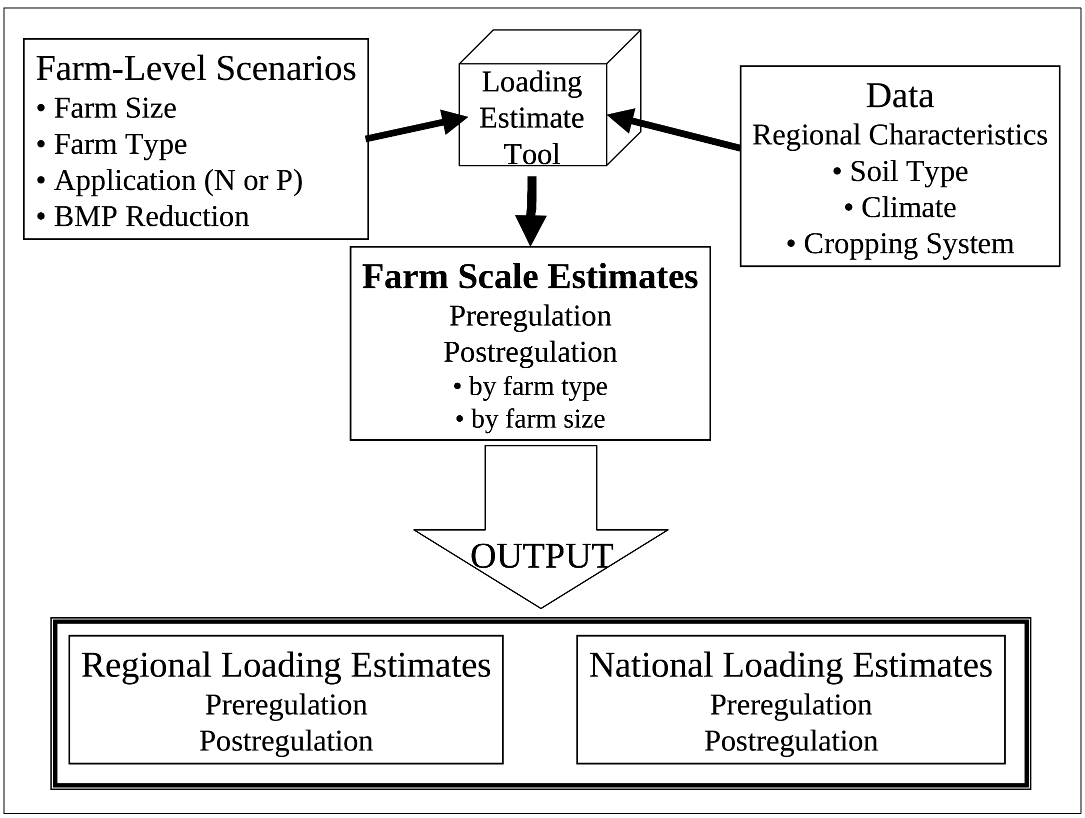


Figure 12. Schematic Depicting the Methodology used in the Pollutant Reduction Loading Model

The GLEAMS model (Knisel et al., 1993) provides edge-of-field output in terms of pounds per acre loading rates. For each of the 13,500 Sample Farm models, these rates can be converted to total edge-of-field loads (per farm) by multiplying them by the number of acres on each farm. For the purposes of generating total (annual) AFO loads and load reductions for use in EPA's benefits analysis, the total edge-of-field loads were incorporated with feedlot runoff, overflow loading reductions, and manure storage structure (lagoon) seepage to produce total facility pollutant loads. These total facility pollutant loads were multiplied by the number of facilities specific to that particular region, size, and sector to obtain regional pollutant loads. These regional pollutant loads were then summed to obtain national pollutant loads.

Five files were used to run GLEAMS: hydrology, precipitation, erosion, nutrient, and pesticide (the pesticide file contains information for pathogens and metals). Only one hydrology, precipitation, and erosion file was necessary for each modeled sector and location. EPA developed individual nutrient and pesticide files, as needed, to reflect the fertilizer application rate and the method of application. Several modeling assumptions and procedures used by EPA to perform its multiyear simulation at each Sample Farm are further detailed below.

A. Climate Database

As mentioned above, for each Sample Farm, GLEAMS was used to simulate continuous edge-of-field performance for a 50-year period. EPA's LET processor contained a looped structure to continuously run the model, using end-of-year conditions to initiate the simulation start for the subsequent year. The first 25-year period of simulation was used to permit the model to reach a local equilibrium, relatively independent of initial input values. EPA's assessment of edge-of-field performance was based on calculated average annual pollutant loadings for the second 25-year period. The 25-year period length was selected to account for weather variability.

B. Crops

For each Sample Farm, the primary model data dictate the sector, location, percentage of head for each state within the region, crop rotation length, crop, crop planting and harvest dates, and nutrient requirements. This rather large file may be found on the CD-ROM containing the Load Model, available in the docket. The percentage of head for each state within a given region is a weighting factor designed to group sectors, one sector in each region.

C. Soils

The simulation of soil behavior for the three most common soils found in top production counties began with the assumption that initial antecedent conditions were "average." In terms of SCS soil modeling terminology, this is referred to as antecedent condition II. For all subsequent days simulated by EPA over the 50-year period, the GLEAMS model estimated and continuously monitored soil pore storage on a daily basis. Hence, the initial condition assumption has minimal influence on the outcome of EPA's simulation.

In its 50-year simulation period, the soil nature (i.e., texture) was not varied over time, neglecting the effects of weathering and erosion on soil nature. This assumption equally affects baseline and revised-rule conditions; and as a result it is believed to have no net impact on EPA's assessment of potential benefits for rule revision.

D. Manure Storage Structures and Production Area Loads

EPA obtained a suite of typical loading rates for direct and indirect pollutant loadings based on a review of literature. As described in Section III.G., the values from the literature were used lending credibility to annual estimates of production area loads.

E. Total Per Farm Loadings

Results of the GLEAMS runs were tabulated by a post-processing routine built into LET. The volume of output produced required EPA to create a large database to contain all the estimated per farm loading rates. Individual results were obtained for all 13,500 Sample Farm models, for each of the regulatory conditions or options outlined in Table 2.

Once the GLEAMS simulations were complete and the loading rate database was constructed, the simulated loads were summed using appropriate weighting factors. These weighting factors represent the following:

- The three dominant soil types by sector for each location
- For multiple sample farms within a region, the ratio of sector specific animal head counts
- The number of acres associated with a particular regulatory option and farm condition
- The number of facilities associated with a particular regulatory option and farm condition

The purpose of these weighting factors is to ultimately generate average edge-of-field loads for each sector in each of the five regions.

VI. National Total Load Estimates by Sector

National nutrient, sediment, metal, and pathogen loads by regulatory option and sector are presented in Table 35 for medium and large together, in Table 36 for medium facilities only, and in Table 37 for large facilities only. These edge-of-field results are averages based on 25 years of daily rain that contain loads from both the cropland and the production area.

Table 35. National Pollutant Loads under Baseline and the Regulatory Scenarios for Medium and Large Operations

Scenario	Operation	Nitrogen		Phosphorus		Sediment	Fecal Coliform	Fecal Streptococcus	Zinc	Copper	Cadmium	Nickel	Lead	Arsenic
		Surface	Leached	Surface	Leached									
		10^3 pounds				10^3 tons	10^{13} cfu*		10^3 pounds					
Baseline	Beef	47,707	81,236	119,495	2,219	9,477	459,523	205,967	1,966	453	3	548	60	193
	Broiler	39,601	121,092	73,119	5,099	12,711	1,769	1,534,900	4,354	628	7	1,441	296	322
	Dairy	29,072	68,303	38,595	3,156	2,573	78,806	459,681	3,869	474	6	1,126	157	193
	Heifer	1,672	5,941	1,083	95	44	19,206	8,609	36	7	0	10	2	2
	Layers	14,482	74,834	36,506	1,261	2,919	7,980	17,028	4,945	288	10	965	164	197
	Layers (wet)	25,169	26,562	15,979	89	771	93,671	199,832	1,462	93	3	226	57	39
	Swine-combined	14,792	32,111	19,380	1,500	1,642	107,894	3,176,891	1,818	223	4	441	75	232
	Swine-slaughter	46,370	96,952	25,422	1,652	2,176	271,106	7,982,553	2,331	289	6	569	96	290
	Turkey	12,139	47,859	24,134	2,368	1,167	714	1,521	3,490	194	3	593	108	275
	Veal	134	205	49	0	1	17	8	14	1	0	4	0	1
	Total	231,137	555,097	353,761	17,440	33,482	1,040,687	13,586,990	24,285	2,652	42	5,923	1,015	1,745
Option 1	Beef	42,429	41,127	103,883	2,219	8,714	433,447	194,230	1,867	441	1	525	60	187
	Broiler	37,670	115,315	70,465	5,099	12,702	1,233	1,070,083	4,323	621	7	1,431	293	315
	Dairy	27,210	51,575	34,102	3,156	2,509	68,209	397,868	3,834	467	5	1,119	157	189
	Heifer	1,680	5,862	1,058	95	45	20,248	9,077	34	7	0	10	2	2
	Layers	12,417	57,724	31,089	1,261	2,913	1,947	4,158	4,787	283	10	962	159	191
	Layers (wet)	25,067	25,804	15,761	89	771	93,628	199,739	1,400	92	3	225	55	39
	Swine-combined	14,781	31,835	19,286	1,500	1,642	107,593	3,168,013	1,814	222	4	441	74	231
	Swine-slaughter	46,366	96,885	25,393	1,652	2,176	270,813	7,973,947	2,330	289	6	569	96	289
	Turkey	11,833	45,156	23,617	2,368	1,166	425	903	3,463	193	3	593	107	273
	Veal	134	205	49	0	1	17	8	14	1	0	4	0	1
	Total	219,587	471,488	324,702	17,439	32,638	997,561	13,018,027	23,867	2,616	39	5,881	1,004	1,717
Option 2	Beef	40,072	40,741	96,231	2,146	8,705	433,388	194,164	1,826	436	1	512	57	169
	Broiler	37,161	115,782	66,314	5,094	12,691	1,233	1,070,013	4,321	621	7	1,428	293	309
	Dairy	26,536	51,172	31,277	3,034	2,483	68,290	398,344	3,730	455	5	1,085	152	180
	Heifer	1,662	5,863	926	95	43	20,250	9,077	34	7	0	10	2	2
	Layers	11,919	56,838	28,535	1,237	2,841	1,946	4,152	4,721	278	10	941	157	184
	Layers (wet)	19,603	26,110	13,286	87	743	65,042	138,756	1,322	88	3	222	52	36
	Swine-combined	13,013	31,611	16,865	1,467	1,592	76,559	2,254,234	1,765	216	4	428	72	223
	Swine-slaughter	43,551	97,053	22,558	1,648	2,144	215,430	6,343,234	2,292	283	5	561	95	282
	Turkey	11,511	45,559	21,697	2,348	1,157	424	903	3,449	192	3	589	106	269
	Veal	134	204	47	0	1	18	8	14	1	0	4	0	1
	Total	205,162	470,933	297,734	17,156	32,401	882,580	10,412,886	23,474	2,577	37	5,781	985	1,655
Option 3	Beef	33,481	40,741	96,231	2,146	8,705	433,388	194,164	1,826	436	1	512	57	169

Scenario	Operation	Nitrogen		Phosphorus		Sediment	Fecal Coliform	Fecal Streptococcus	Zinc	Copper	Cadmium	Nickel	Lead	Arsenic
		Surface	Leached	Surface	Leached									
		10^3 pounds				10^3 tons	10^{13} cfu*		10^3 pounds					
	Broiler	37,161	115,782	66,314	5,094	12,691	1,233	1,070,013	4,321	621	7	1,428	293	309
	Dairy	21,709	51,172	31,277	3,034	2,483	68,290	398,344	3,730	455	5	1,085	152	180
	Heifer	992	5,863	926	95	43	20,250	9,077	34	7	0	10	2	2
	Layers	11,919	56,838	28,535	1,237	2,841	1,946	4,152	4,721	278	10	941	157	184
	Layers (wet)	17,909	26,110	13,286	87	743	65,042	138,756	1,322	88	3	222	52	36
	Swine-combined	12,293	31,611	16,865	1,467	1,592	76,559	2,254,234	1,765	216	4	428	72	223
	Swine-slaughter	32,587	97,053	22,558	1,648	2,144	215,430	6,343,234	2,292	283	5	561	95	282
	Turkey	11,511	45,559	21,697	2,348	1,157	424	903	3,449	192	3	589	106	269
	Veal	126	204	47	0	1	18	8	14	1	0	4	0	1
	Total	179,690	470,933	297,734	17,156	32,401	882,580	10,412,886	23,474	2,577	37	5,781	985	1,655
Option 5	Beef	40,072	40,741	96,231	2,146	8,705	433,388	194,164	1,826	436	1	512	57	169
	Broiler	37,161	115,782	66,314	5,094	12,691	1,233	1,070,013	4,321	621	7	1,428	293	309
	Dairy	26,536	51,172	31,277	3,034	2,483	68,290	398,344	3,730	455	5	1,085	152	180
	Heifer	1,662	5,863	926	95	43	20,250	9,077	34	7	0	10	2	2
	Layers	11,919	56,838	28,535	1,237	2,841	1,946	4,152	4,721	278	10	941	157	184
	Layers (wet)	14,322	26,110	12,142	87	720	36,456	77,772	1,250	85	3	221	49	36
	Swine-combined	12,131	47,679	14,871	1,756	1,809	45,368	1,335,840	1,908	226	3	490	81	232
	Swine-slaughter	41,238	111,068	19,906	1,856	2,295	159,844	4,706,533	2,355	282	5	604	100	280
	Turkey	11,511	45,559	21,697	2,348	1,157	424	903	3,449	192	3	589	106	269
	Veal	134	204	47	0	1	15	7	14	1	0	4	0	1
	Total	**196,685**	**501,016**	**291,945**	**17,653**	**32,746**	**767,214**	**7,796,806**	**23,608**	**2,583**	**36**	**5,885**	**996**	**1,661**

* colony forming units

Table 36. National Pollutant Loads under Baseline and the Regulatory Scenarios for Medium Operations

Scenario	Operation	Nitrogen Surface	Nitrogen Leached	Phosphorus Surface	Phosphorus Leached	Sediment	Fecal Coliform	Fecal Streptococcus	Zinc	Copper	Cadmium	Nickel	Lead	Arsenic
		10^3 pounds				10^3 tons	10^{13} cfu*		10^3 pounds					
Baseline	Beef	10,147	13,101	16,592	268	2,290	22,042	9,888	246	54	0	69	8	42
	Broiler	25,889	78,891	47,689	3,265	8,450	1,261	1,094,214	2,872	418	5	952	197	207
	Dairy	18,201	37,951	21,775	1,568	1,402	43,579	254,200	2,264	262	3	657	86	122
	Heifer	979	3,064	686	35	40	203	91	15	3	0	4	1	1
	Layers	3,164	15,207	7,935	322	672	1,446	3,085	984	58	2	190	33	37
	Layers (wet)	9,111	7,363	4,532	23	221	37,137	79,225	390	26	1	62	16	11
	Swine-combined	6,244	12,061	7,597	224	732	52,468	1,544,887	702	88	2	174	29	82
	Swine-slaughter	28,183	54,787	13,426	354	1,224	187,187	5,511,619	1,183	151	3	289	49	138
	Turkey	6,260	27,309	13,576	1,400	703	377	803	1,873	108	1	301	60	145
	Veal	134	205	49	0	1	17	8	14	1	0	4	0	1
	Total	**108,311**	**249,939**	**133,858**	**7,460**	**15,735**	**345,718**	**8,498,019**	**10,543**	**1,169**	**17**	**2,702**	**479**	**785**
Option 1	Beef	10,009	13,069	16,537	268	2,289	9,944	4,464	245	54	0	69	8	42
	Broiler	25,710	78,449	47,473	3,265	8,449	1,201	1,042,187	2,870	417	5	951	197	207
	Dairy	17,389	34,166	20,442	1,568	1,400	34,292	200,028	2,247	259	3	655	86	121
	Heifer	990	3,056	685	35	41	1,282	574	14	3	0	4	1	1
	Layers	3,157	15,137	7,909	322	672	1,418	3,027	983	58	2	190	33	37
	Layers (wet)	9,111	7,363	4,532	23	221	37,137	79,225	390	26	1	62	16	11
	Swine-combined	6,243	12,048	7,594	224	732	52,442	1,544,118	702	88	2	174	29	82
	Swine-slaughter	28,182	54,773	13,422	354	1,224	187,146	5,510,406	1,183	151	3	289	49	138
	Turkey	6,250	27,209	13,556	1,400	703	370	788	1,871	108	1	301	60	145
	Veal	134	205	49	0	1	17	8	14	1	0	4	0	1
	Total	**107,176**	**245,475**	**132,199**	**7,460**	**15,732**	**325,249**	**8,384,826**	**10,521**	**1,165**	**17**	**2,698**	**479**	**784**
Option 2	Beef	9,975	13,058	16,322	267	2,280	9,939	4,461	245	54	0	69	8	41
	Broiler	25,674	78,487	47,119	3,265	8,448	1,201	1,042,182	2,870	417	5	951	197	206
	Dairy	17,165	33,972	19,312	1,538	1,374	34,316	200,167	2,211	256	3	643	85	117
	Heifer	978	3,054	631	35	39	1,282	574	14	3	0	4	1	1
	Layers	3,155	15,135	7,888	322	672	1,418	3,027	983	58	2	190	33	37
	Layers (wet)	9,042	7,366	4,506	23	221	36,765	78,433	389	26	1	62	16	11
	Swine-combined	6,034	12,027	7,363	223	728	48,563	1,429,904	698	88	2	173	29	81

Scenario	Operation	Nitrogen Surface	Nitrogen Leached	Phosphorus Surface	Phosphorus Leached	Sediment	Fecal Coliform	Fecal Streptococcus	Zinc	Copper	Cadmium	Nickel	Lead	Arsenic
		10^3 pounds				10^3 tons	10^{13} cfu*		10^3 pounds					
	Swine-slaughter	27,491	54,746	12,961	354	1,218	173,195	5,099,641	1,175	150	3	288	49	136
	Turkey	6,239	27,213	13,503	1,399	703	370	788	1,871	107	1	301	60	145
	Veal	134	204	47	0	1	18	8	14	1	0	4	0	1
	Total	**105,886**	**245,263**	**129,652**	**7,426**	**15,683**	**307,068**	**7,859,185**	**10,470**	**1,160**	**16**	**2,683**	**477**	**777**
Option 3	Beef	9,744	13,058	16,322	267	2,280	9,939	4,461	245	54	0	69	8	41
	Broiler	25,674	78,487	47,119	3,265	8,448	1,201	1,042,182	2,870	417	5	951	197	206
	Dairy	15,126	33,972	19,312	1,538	1,374	34,316	200,167	2,211	256	3	643	85	117
	Heifer	703	3,054	631	35	39	1,282	574	14	3	0	4	1	1
	Layers	3,155	15,135	7,888	322	672	1,418	3,027	983	58	2	190	33	37
	Layers (wet)	9,027	7,366	4,506	23	221	36,765	78,433	389	26	1	62	16	11
	Swine-combined	5,977	12,027	7,363	223	728	48,563	1,429,904	698	88	2	173	29	81
	Swine-slaughter	25,418	54,746	12,961	354	1,218	173,195	5,099,641	1,175	150	3	288	49	136
	Turkey	6,239	27,213	13,503	1,399	703	370	788	1,871	107	1	301	60	145
	Veal	126	204	47	0	1	18	8	14	1	0	4	0	1
	Total	**101,188**	**245,263**	**129,652**	**7,426**	**15,683**	**307,068**	**7,859,185**	**10,470**	**1,160**	**16**	**2,683**	**477**	**777**
Option 5	Beef	9,975	13,058	16,322	267	2,280	9,939	4,461	245	54	0	69	8	41
	Broiler	25,674	78,487	47,119	3,265	8,448	1,201	1,042,182	2,870	417	5	951	197	206
	Dairy	17,165	33,972	19,312	1,538	1,374	34,316	200,167	2,211	256	3	643	85	117
	Heifer	978	3,054	631	35	39	1,282	574	14	3	0	4	1	1
	Layers	3,155	15,135	7,888	322	672	1,418	3,027	983	58	2	190	33	37
	Layers (wet)	8,973	7,366	4,491	23	221	36,394	77,641	388	26	1	62	16	11
	Swine-combined	5,834	13,046	7,098	225	732	44,664	1,315,111	695	87	2	174	29	80
	Swine-slaughter	26,786	56,200	12,426	354	1,217	159,211	4,687,871	1,162	147	3	288	48	134
	Turkey	6,239	27,213	13,503	1,399	703	370	788	1,871	107	1	301	60	145
	Veal	134	204	47	0	1	15	7	14	1	0	4	0	1
	Total	**104,913**	**247,737**	**128,837**	**7,428**	**15,687**	**288,812**	**7,331,830**	**10,453**	**1,156**	**16**	**2,684**	**476**	**774**

* colony forming units

Table 37. National Pollutant Loads under Baseline and the Regulatory Scenarios for Large Operations

Scenario	Operation	Nitrogen Surface	Nitrogen Leached	Phosphorus Surface	Phosphorus Leached	Sediment	Fecal Coliform	Fecal Streptococcus	Zinc	Copper	Cadmium	Nickel	Lead	Arsenic
		10^3 pounds				10^3 tons	10^{13} cfu*		10^3 pounds					
Baseline	Beef	37,560	68,135	102,903	1,951	7,187	437,481	196,079	1,720	399	3	479	52	152
	Broiler	13,712	42,201	25,430	1,834	4,261	508	440,686	1,482	210	3	489	99	115
	Dairy	10,871	30,352	16,819	1,588	1,172	35,227	205,481	1,606	212	3	468	71	72
	Heifer	694	2,877	397	60	4	19,003	8,518	21	4	0	6	1	1
	Layers	11,318	59,628	28,571	939	2,246	6,535	13,943	3,961	230	8	775	131	160
	Layers (wet)	16,057	19,199	11,447	66	550	56,534	120,607	1,072	68	2	164	41	29
	Swine-combined	8,548	20,050	11,783	1,276	910	55,427	1,632,004	1,116	135	2	268	45	150
	Swine-slaughter	18,187	42,165	11,995	1,298	953	83,919	2,470,934	1,147	138	3	280	47	152
	Turkey	5,879	20,551	10,558	968	464	337	718	1,617	87	1	292	48	130
	Veal	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	**122,826**	**305,158**	**219,903**	**9,980**	**17,747**	**694,969**	**5,088,970**	**13,742**	**1,483**	**25**	**3,221**	**536**	**960**
Option 1	Beef	32,420	28,058	87,346	1,951	6,425	423,504	189,765	1,622	386	1	456	52	145
	Broiler	11,960	36,867	22,991	1,834	4,253	32	27,896	1,453	204	2	480	97	108
	Dairy	9,820	17,408	13,660	1,588	1,109	33,917	197,841	1,587	208	3	464	71	68
	Heifer	690	2,806	373	60	4	18,966	8,502	20	4	0	6	1	1
	Layers	9,260	42,587	23,180	939	2,240	529	1,131	3,804	225	8	773	126	154
	Layers (wet)	15,956	18,441	11,229	66	550	56,491	120,515	1,010	66	2	163	40	28
	Swine-combined	8,538	19,787	11,692	1,276	910	55,151	1,623,895	1,112	134	2	268	45	149
	Swine-slaughter	18,184	42,112	11,970	1,298	953	83,667	2,463,541	1,146	138	3	280	47	152
	Turkey	5,583	17,947	10,061	968	462	55	116	1,591	86	1	292	48	128
	Veal	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	**112,411**	**226,013**	**192,503**	**9,979**	**16,906**	**672,312**	**4,633,201**	**13,345**	**1,451**	**23**	**3,182**	**526**	**933**
Option 2	Beef	30,096	27,683	79,909	1,879	6,425	423,449	189,704	1,581	381	1	443	49	127
	Broiler	11,487	37,295	19,195	1,829	4,243	32	27,831	1,450	204	2	477	96	103
	Dairy	9,371	17,200	11,964	1,496	1,109	33,974	198,177	1,519	200	2	442	67	63
	Heifer	684	2,809	295	60	4	18,967	8,502	20	4	0	6	1	1
	Layers	8,765	41,702	20,647	915	2,169	527	1,125	3,739	220	8	752	124	147
	Layers (wet)	10,561	18,744	8,779	65	522	28,276	60,322	933	62	2	160	36	26
	Swine-combined	6,979	19,585	9,502	1,244	865	27,996	824,330	1,066	128	2	256	43	142

Scenario	Operation	Nitrogen Surface	Nitrogen Leached	Phosphorus Surface	Phosphorus Leached	Sediment	Fecal Coliform	Fecal Streptococcus	Zinc	Copper	Cadmium	Nickel	Lead	Arsenic
		10^3 pounds				10^3 tons	10^{13} cfu*		10^3 pounds					
	Swine-slaughter	16,060	42,306	9,597	1,294	927	42,235	1,243,594	1,117	133	2	273	46	146
	Turkey	5,272	18,346	8,195	949	454	54	116	1,578	85	1	288	46	124
	Veal	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	**99,275**	**225,670**	**168,083**	**9,730**	**16,717**	**575,511**	**2,553,701**	**13,004**	**1,417**	**21**	**3,098**	**508**	**878**
Option 3	Beef	23,737	27,683	79,909	1,879	6,425	423,449	189,704	1,581	381	1	443	49	127
	Broiler	11,487	37,295	19,195	1,829	4,243	32	27,831	1,450	204	2	477	96	103
	Dairy	6,583	17,200	11,964	1,496	1,109	33,974	198,177	1,519	200	2	442	67	63
	Heifer	289	2,809	295	60	4	18,967	8,502	20	4	0	6	1	1
	Layers	8,765	41,702	20,647	915	2,169	527	1,125	3,739	220	8	752	124	147
	Layers (wet)	8,882	18,744	8,779	65	522	28,276	60,322	933	62	2	160	36	26
	Swine-combined	6,316	19,585	9,502	1,244	865	27,996	824,330	1,066	128	2	256	43	142
	Swine-slaughter	7,169	42,306	9,597	1,294	927	42,235	1,243,594	1,117	133	2	273	46	146
	Turkey	5,272	18,346	8,195	949	454	54	116	1,578	85	1	288	46	124
	Veal	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	**78,502**	**225,670**	**168,083**	**9,730**	**16,717**	**575,511**	**2,553,701**	**13,004**	**1,417**	**21**	**3,098**	**508**	**878**
Option 5	Beef	30,096	27,683	79,909	1,879	6,425	423,449	189,704	1,581	381	1	443	49	127
	Broiler	11,487	37,295	19,195	1,829	4,243	32	27,831	1,450	204	2	477	96	103
	Dairy	9,371	17,200	11,964	1,496	1,109	33,974	198,177	1,519	200	2	442	67	63
	Heifer	684	2,809	295	60	4	18,967	8,502	20	4	0	6	1	1
	Layers	8,765	41,702	20,647	915	2,169	527	1,125	3,739	220	8	752	124	147
	Layers (wet)	5,348	18,744	7,651	65	499	61	131	862	59	2	160	33	25
	Swine-combined	6,297	34,633	7,774	1,532	1,077	704	20,729	1,213	139	2	317	52	151
	Swine-slaughter	14,451	54,867	7,479	1,502	1,078	634	18,661	1,193	135	2	317	51	147
	Turkey	5,272	18,346	8,195	949	454	54	116	1,578	85	1	288	46	124
	Veal	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	**91,772**	**253,279**	**163,109**	**10,226**	**17,059**	**478,403**	**464,976**	**13,155**	**1,427**	**20**	**3,201**	**519**	**888**

* colony forming units

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